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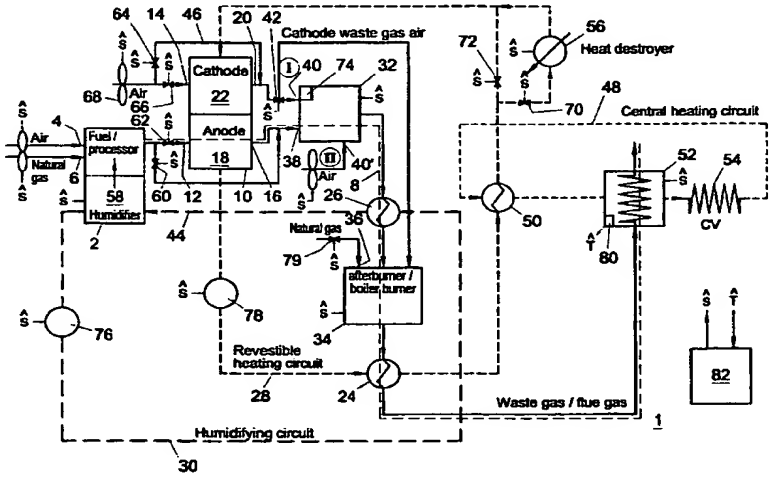
(54) Title: FUEL CELL SYSTEM FOR GENERATING ELECTRIC ENERGY AND HEAT



(57) Abstract: The system is provided with a fuel processor (2) for generating hydrogen from a hydrocarbon compound or from mixtures of hydrocarbon compounds and a combustion path (8), along which the generated hydrogen is passed for combustion. Included in the combustion path is at least one fuel cell (10) for generating electric energy. The system is further provided with a first heat exchanger (24) and a second heat exchanger (26) which, on the one hand, are series included in the combustion path dowsntream of the fuel cell, a first heating circuit (28) in which the fuel cell is included, and a second heating circuit (30) in which the fuel processed is included. The first heat exchanger, on the other hand, is included in the first heating circuit. The second heat exchanger, on the other hand, is included in the second heating circuit.

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— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

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FUEL CELL SYSTEM FOR GENERATING ELECTRIC ENERGY AND HEAT

The invention relates to a system provided with a fuel processor for generating hydrogen from a hydrocarbon compound and a combustion path, along which the generated hydrogen is passed for combustion, and in which combustion path at least one fuel cell is included for at least generating electric energy and optionally heat through combustion of the hydrogen generated by the fuel processor.

Such systems are known per se. In these known systems the energy production of the fuel cell is integrated, by means of heat exchange, with the energy requirement of the fuel processor, in particular for generating steam, but also for the supply of energy for H_2 production via the endothermic steam reforming reaction. Such a system is not suitable for providing, for instance, a building or house with a strongly varying amount of electric energy. Also, the system is not suitable for starting up autonomously. The fact is that, in full operation, both the fuel cell and the fuel processor must be provided with heat. Methods have already been described for the startup of the fuel cell with heat generated by a stationarily operating fuel processor. The problem with this method still is, however, that the fuel processor must be started up while heat is supplied.

The present invention has for its object to provide one system for both the integration of the energy product of the fuel cell with the energy requirement of the fuel processor and for the simultaneous startup of the fuel cell and the fuel processor. Also, the system should be able to satisfy a variable energy requirement.

To this end, the system according to the invention is characterized in that the system is further provided with a first heat exchanger and a second heat exchanger which, on the one hand, are series included in the combustion path downstream of the fuel cell, a first heating circuit in which the fuel cell is included, and a second heating circuit in which the fuel processor is included, which first heat exchanger, on the other hand, is included in the first heating

circuit for exchanging heat between the combustion path and the first heating circuit, and which second heat exchanger, on the other hand, is included in the second heating circuit for exchanging heat between the combustion path and the second heating circuit.

Because of the first and the second heating circuit, when starting up respectively the fuel cell and the fuel processor can be provided with heat. In operation, the first heating circuit can even be used to discharge an excess of energy generated by the fuel cell for other purposes, as will be further explained below.

In particular, it holds that the system is further provided with a waste gas burner included in the combustion path between the fuel cell and the second heat exchanger. By means of the waste gas burner the hydrogen not yet completely burned by the fuel cell can still be, at least almost, completely burned.

More in particular, it holds that the system is further provided with a burner included in the combustion path between the first and the second heat exchanger, which has the function of after burner or boiler burner.

According to the invention the burner can be utilized as afterburner for hydrogen which even the waste gas burner has not yet completely burned.

In particular, it holds that the waste gas burner is further provided with at least one first inlet included in the combustion path and a second inlet for supplying air. More in particular, it holds in this connection that the system is arranged such that waste gas air originating from the fuel cell or air from elsewhere can be supplied to the waste gas burner. The fuel cell is provided with a first inlet connected with the fuel processor for supplying hydrogen to the fuel cell, a second inlet for supplying air to the fuel cell, a first outlet for discharging waste gas from an anode of the fuel cell and a second outlet for discharging waste gas air from a cathode of the fuel cell.

In this connection, it preferably holds that the first outlet of the fuel cell is connected with the first inlet of the waste gas burner included in the

combustion path. The second outlet of the fuel cell may then be connected with the burner for supplying waste gas air from the fuel cell to the burner. Preferably, it holds that via a control valve the second outlet is also connected with the second outlet of the waste gas burner to supply waste gas air to the waste gas burner. It is also possible, however, to use a separate air supply.

According to an advanced embodiment of the system it holds that the system is further provided with a controllable first bypass connection for bridging the first inlet and the first outlet of the fuel cell when starting up the system. In this connection, it preferably holds that the system is further provided with a second bypass connection for bridging the second inlet and the second outlet of the fuel cell when starting up.

According to a very suitable use of the system according to the invention it holds that the system is further provided with a central heating circuit and a third heat exchanger for exchanging heat between the first heating circuit and the central heating circuit. The central heating circuit can be provided with a heat exchanger included in the combustion path downstream of the first heat exchanger and capable of functioning as boiler system in combination with the afterburner. In particular, it holds that the first heating circuit is designed as a reversible heating circuit in which a heat transport medium can be selectively pumped round in two directions. The first heating circuit has a double function. When starting up, the fluid flows in the heating circuit of the first heat exchanger to the fuel cell, from the fuel cell to the third heat exchanger, and from the third heat exchanger to the first heat exchanger. The burner can be in operation and burns on waste gas from the waste gas burner and air via the second bypass of the fuel cell. The combustion gases heat the fuel cell.

During stationary operation the burner is basically inoperative. The fluid in the first combustion circuit flows in a direction opposite to the direction when starting up. This involves that the heat of the fuel cell is discharged to the third heat exchanger forming part of the central heating.

When the residual heat to this heat exchanger in the fluid is too high to sufficiently cool the fuel cell, the heat can be removed from the first heating circuit by means of a heat destroyer included in this heating circuit, such as a fin. If, however, the fuel cell does not generate sufficient heat for the central heating system, the burner can be used as boiler burner. To this end, the burner is provided with an additional connection to which, for instance, natural gas can be supplied. Combustion heat is then supplied via the first heating circuit and via the flue gases from the burner to the central heating circuit.

In principle, it holds for the system that the electricity demand is leading. The residual energy demand is covered by operating the burner as boiler burner.

The invention will now be explained in more detail with reference to the drawing in which:

Fig. 1 is a schematic diagram of a possible embodiment of the system according to the invention.

In Fig. 1 reference numeral 1 denotes a system according to the invention. The system is provided with a fuel processor 2 for generating hydrogen from a hydrocarbon compound or a mixture of hydrocarbon compounds. To this end, the fuel processor is provided with a first inlet 4 for supplying air and a second inlet 6 for supplying the gaseous hydrocarbon compound or the mixture of hydrocarbon compounds, in this example natural gas. The system is further provided with a combustion path along which the hydrogen generated by the fuel processor 2 is passed for combustion. In the figure this combustion path is denoted by the dotted line 8.

Included in the combustion path 8 is a fuel cell 10 of a known per se type for at least generating electric energy E and optionally heat Q through combustion of the hydrogen generated by the fuel processor 2. In this example the fuel cell is provided with a first inlet 12 which is connected with an outlet of the fuel processor 2 for supplying hydrogen to the fuel cell. Furthermore, the

fuel cell is provided with a second inlet 14 for supplying air to the fuel cell. The fuel cell is further provided with a first outlet 16 for discharging waste gas from an anode 18 of the fuel cell and a second outlet 20 for discharging waste gas air from a cathode 22 of the fuel cell.

The system is further provided with a first heat exchanger 24 and a second heat exchanger 26 which, on the one hand, are series included in the combustion path 8 downstream of the fuel cell 10. The system further comprises a first heating circuit 28 in which the fuel cell is included and a second heating circuit 30 in which the fuel processor is included. The first heat exchanger, on the other hand, is included in the first heating circuit 28 for exchanging heat between the combustion path 8 and the first heating circuit. The second heat exchanger 26 is, on the other hand, included in the second heating circuit 30 for exchanging heat between the combustion path 8 and the second heating circuit 30.

The system is further provided with a known per se catalytic waste gas burner 32 included in the combustion path between the fuel cell 10 and the second heat exchanger 26. Included between the first heat exchanger 24 and the second heat exchanger 26 in the combustion path 8 is a burner 34 which may have the function of afterburner or boiler burner. This involves that the fuel cell 10, the waste gas burner 32, the second heat exchanger 26, the burner 34, and the first heat exchanger 24 are series included in the combustion path 8. The burner 34 is further provided with a separate inlet 36 for supplying a gas, such as natural gas. The waste gas burner 32 is further provided with at least one first inlet 38 included in the combustion path 8 and a second inlet 40 for supplying air. In this example the second outlet 20 of the fuel cell 10 is connected with the second inlet 40 of the waste gas burner. It is also possible, however, that the waste gas burner is provided with a separate inlet 40' for supplying air to the waste gas burner. The system is therefore arranged such that waste gas air originating from the fuel cell or air from elsewhere can be supplied to the waste gas burner via respectively the inlet 40 and 40'.

The first outlet 16 of the fuel cell 10 is connected with the first inlet 38 of the waste gas burner 32 included in the combustion path 8. The second outlet 20 of the fuel cell is connected with the burner 34 for supplying waste gas air from the fuel cell 10 to the burner 34. In this example it holds that the second outlet 20 of the fuel cell, via a control valve 42, is also connected with the second inlet 40 of the waste gas burner for supplying waste gas air or air to the waste gas burner 32.

The system is further provided with a controllable first bypass connection 44 for bridging the first inlet 12 and the first outlet 16 of the fuel cell 10 when starting up the system. Also, the system is provided with a second bypass connection 46 for bridging the second inlet 14 and the second outlet 20 of the fuel cell 10 when starting up. In this example the system further comprises a central heating circuit 48 and a third heat exchanger 50 for exchanging heat between the first heating circuit 28 and the central heating circuit 48. The central heating circuit 48 is provided with a heat exchanger 52 included in the combustion path 8 downstream of the first heat exchanger 24. Thus, waste gas flown through the first heat exchanger is supplied to the heat exchanger 52. Besides the third heat exchanger 50 and the heat exchanger 52 a central heating 54 is also included in the central heating circuit 48.

In this example the first heating circuit is designed as a reversible circuit in which a heat transport medium can be selectively pumped round in two directions. The system is further provided with a heat destroyer 56 in the form of, for instance, a fin included in the first heating circuit 28 between the fuel cell 10 and the third heat exchanger 50 for discharging an adjustable amount of heat from the first heating circuit 28.

In this example the fuel processor 2 is provided with humidifying means 58 for humidifying a mixture of natural gas and air, which natural gas and air is supplied to the fuel processor via the first inlet 4 and the second inlet 6. To this end, the humidifying means 58 are provided in this example with a reservoir with water, which reservoir is included in the second heat exchanger

30 for heating the water and for thus adding water vapor to the above mixture. The arrangement is further provided with control valves 60, 62 for adjustably distributing the hydrogen generated by the fuel processor 2 to the first inlet 12 of the fuel cell 10 and the bypass 44. Furthermore, the arrangement is provided with valves 64, 66 for adjustably distributing air drawn in by means of a ventilator 68 via the second inlet 14 of the fuel cell 10 and the second bypass 48. By means of valves 70, 72 the medium flowing through the heating circuit 28 can be passed through the heat destroyer 56 completely or partly, as desired.

The system as described before operates as follows.

When starting up, the fuel processor is not yet heated and will therefore not yet be able to generate gas rich in hydrogen. In a first step natural gas is passed to the fuel processor, mixed with deficient combustion air. In the processor this mixture is burned to form CO and H_2. The combustion can take place thermally or catalytically, by means of respectively an electric ignition or an electric heating for starting up the catalyst. When starting up, the valves 60, 62 are arranged such that the mixture of CO, H_2 and unburned natural gas leaving the fuel processor 2 is passed via the bypass 44 to the inlet 38 of the waste gas burner 32. Also, the valves 64, 66 are operated such that air drawn in by means of the ventilator 68 is supplied via bypass 46 and the control valve 42 to the burner 34. Moreover, via the control valve 42 a part of the above air can be supplied to the inlet 40 of the waste gas burner 32. When starting up. the waste gas burner 32 is heated by means of a heating unit 74 of the waste gas burner. The heating unit 74 can, for instance, be designed as an electric heating. The result is that the gas mixture from the fuel processor 2 will burn with the air in the waste gas burner 32. As a result, the temperature of the waste gas burner will rise further. The resulting waste gas from the waste gas burner 32 is supplied via the second heat exchanger 26 to the burner 34. As discussed, air is supplied to the burner 34 as well. Unburned components still

present in the waste gas are burned in the burner 34, after which the waste gas thus generated is supplied to the first heat exchanger 24.

When starting up, a heat transport medium from the second heating circuit is pumped round by means of a pump 76 such that this medium flows from the second heat exchanger 26 to the humidifying means 58 of the fuel processor. The result is that water vapor is added to the mixture of air and natural gas which is supplied to the fuel processor via the first inlet 4 and the second inlet 6. As a result, the fuel processor will begin to generate gas rich in hydrogen. The complete startup of this H_2 production can take up to a few hours. During this period a heat transport medium is pumped round by means of a pump 78 included in the heating circuit, in such a manner that this heat transport medium flows from the first heat exchanger 24 to the fuel cell 10, from the fuel cell 10 to the third heat exchanger 50, and from the third heat exchanger 50 back to the first heat exchanger 24. The result is that the fuel cell 10 is heated as well.

When the fuel cell 10 is heated, while, moreover, the fuel processor generates gas rich in hydrogen, the valves 60 and 62 are operated such that the hydrogen generated by the fuel processor 2 is supplied to the first inlet 12 of the fuel cell. The first bypass 44 is made inoperative. Also, the air drawn in by means of the ventilator 68 is passed to the second inlet 14 of the fuel cell. This means that the second bypass 46 is also made inoperative. Moreover, the burner 34 becomes inoperative. Besides, the pump 78 is controlled such that it begins to pump round the heat transport medium in an opposite direction, i.e. from the fuel cell 10 to the first heat exchanger 24, from the first heat exchanger 24 to the third heat exchanger 50, and from the third heat exchanger 50 back to the fuel cell 10.

In this situation the hydrogen gas supplied to the fuel cell 10 will burn, at least partly. As a result, the fuel cell 10 will generate electric power E offered for, for instance, the use of electricity in a house. The waste gas is supplied via the outlet 16 of the anode 18 to the inlet 38 of the waste gas

burner. Simultaneously, a part of the waste gas air is supplied from the outlet 20 of the cathode via the control valve 42 to the inlet 40 of the waste gas burner. The control valve is adjusted such that the remaining part of the waste gas air continues to flow from the outlet 20 of the cathode through the burner 34, also after it has been extinguished. In the waste gas burner the waste gas originating from the fuel cell 10, as far as the hydrogen had not yet been completely burned herein, is burned further. The waste gas thereby produced in the waste gas burner 32 then flows through the second heat exchanger 26, the burner 34 which is extinguished, and the first heat exchanger 24. The second heat exchanger 26 ensures that heat is continuously supplied to the humidifying means 58. The first heat exchanger 24 now has the function to ensure that the fuel cell 10 is cooled. Heat is supplied via the second heat exchanger 26 to the third heat exchanger 50. The third heat exchanger 50 thereby transmits heat to the central heating circuit 48. Furthermore, the waste gas flown through the first heat exchanger 24 is supplied to the heat exchanger 52. The medium flowing through the central heating circuit 48 then transmits its heat to the central heating 54 which, in a house, may comprise known per se radiators. The heat exchanger 52 is provided in this example with a temperature sensor 80 for measuring the temperature of the medium flowing through the central heating circuit 48. When it appears that the temperature is not high enough to comply with the amount of heat demanded by the central heating 54, the burner 34 can be activated so that it begins to function as boiler burner. A valve 79 is opened for this purpose. To this end, natural gas is supplied via the inlet 36 to the burner 34. This has the result that the waste gas from the waste gas burner 32 flowing through the burner 34 will be heated further. This heated waste gas, mixed with flue gas from the burner 34, flows through the first heat exchanger and can thus transmit a part of the heat content to the heating circuit 28 which, in turn, transmits heat to the central heating circuit via the third heat exchanger 50. The mixture of flue gas and waste gas flows after the first heat exchanger 24 via the combustion

path 8 to the heat exchanger 52 where the gas transmits a next part of the heat content to the central heating circuit. The burner 34 and the heat exchanger 52 thus begin to function as boiler.

The use of a catalytic waste gas burner has the further advantage that peak loads can be properly taken up.

When, for instance, the electricity demand is low and from the fuel cell only a minor amount of residual hydrogen flows via the outlet 16 to the inlet 38 of the waste gas burners, the waste gas burner is yet capable of properly burn this. When, however, the electricity demand is high and relatively much residual hydrogen is released by the fuel cell, the waste gas burner can also properly function. When the composition of the waste gas supplied via bypass 44 from the fuel processor 2 to the inlet 38 of the waste gas burner strongly varies when starting up, through the transition of waste gas with relatively much unburned natural gas to a mixture rich in hydrogen, the waste gas burner is yet capable of properly burning this varying mixture.

It is also possible that the waste gas burner is provided with air via a separate inlet 40'. In that case the control valve 42 can be omitted. The second outlet 20 is then only connected with the afterburner 34.

The system is further provided with a control device 82 for controlling the valves 42, 60, 62, 64, 66, 70 and 72, as discussed before. Also, the control device 82 controls the ventilators 68 and 84, the pump 76, the pump 78, the boiler 52, and the central heating 54 as discussed before. The control unit 82 is also connected with the temperature sensor 80 for determining whether it is necessary to operate the burner 34 as boiler burner, as discussed before. The control unit 82 correspondingly controls the burner 34 and the valve 79 for the supply of natural gas to the inlet 36 of the burner, as discussed before.

The invention is in no way limited to the embodiments described before. Thus it is possible that the burner 34 is provided with a separate inlet for the supply of air. It is therefore not necessary that the burner is provided with air originating from the ventilator 68 and supplied or not supplied via the fuel cell

10 and/or the bypass 56 to the burner. In that case the bypass 56 can be omitted. Such variants are each deemed to fall within the scope of the invention.

Claims

1. A system provided with a fuel processor for generating hydrogen from a hydrocarbon compound and a combustion path, along which the generated hydrogen is passed for combustion, and in which combustion path at least one fuel cell is included for at least generating electric energy and optionally heat through combustion of the hydrogen generated by the fuel processor, characterized in that the system is further provided with a first heat exchanger and a second heat exchanger which, on the one hand, are series included in the combustion path downstream of the fuel cell, a first heating circuit in which the fuel cell is included ,and a second heating circuit in which the fuel processor is included, which first heat exchanger, on the other hand, is included in the first heating circuit for exchanging heat between the combustion path and the first heating circuit, and which second heat exchanger, on the other hand, is included in the second heating circuit for exchanging heat between the combustion path and the second heating circuit.

2. A system according to claim 1, characterized in that the system is further provided with a waste gas burner included in the combustion path between the fuel cell and the second heat exchanger.

3. A system according to claim 1 or 2, characterized in that the system is further provided with an afterburner or boiler burner included in the combustion path between the first and the second heat exchanger.

4. A system according to claim 2 and 3, characterized in that the fuel cell, waste gas burner, second heat exchanger, afterburner and first heat exchanger are series connected.

5. A system according to claim 3 or 4, characterized in that the afterburner is further provided with a separate inlet for supplying a gas, such as natural gas.

6. A system according to any one of claims 2, 4 or 5, characterized in that the waste gas burner is further provided with at least one first inlet included in the combustion path and a second inlet for supplying air.

7. A system according to claim 6, characterized in that the system is arranged such that waste gas air originating from the fuel cell or air from elsewhere can be supplied to the waste gas burner.

8. A system according to any one of the preceding claims, characterized in that the fuel cell is provided with a first inlet connected with the fuel processor for supplying hydrogen to the fuel cell, a second inlet for supplying air to the fuel cell, a first outlet for discharging waste gas from an anode of the fuel cell and a second outlet for discharging waste gas air from a cathode of the fuel cell.

9. A system according to claims 7 and 8, characterized in that the first outlet of the fuel cell is connected with the first inlet of the waste gas burner included in the combustion path.

10. A system according to claim 9, characterized in that the second outlet of the fuel cell is connected with the afterburner for supplying waste gas air from the fuel cell to the afterburner.

11. A system according to claim 10, characterized in that via a control valve the second outlet is also connected with the second outlet of the waste gas burner to supply waste gas air to the waste gas burner.

12. A system according to any one of claims 8-11, characterized in that the system is further provided with a controllable first bypass connection for bridging the first inlet and the first outlet of the fuel cell when starting up the system.

13. A system according to claim 12, characterized in that the system is further provided with a second bypass connection for bridging the second inlet and the second outlet of the fuel cell when starting up the system.

14. A system according to any one of the preceding claims, characterized in that the system is further provided with a central heating circuit and a third

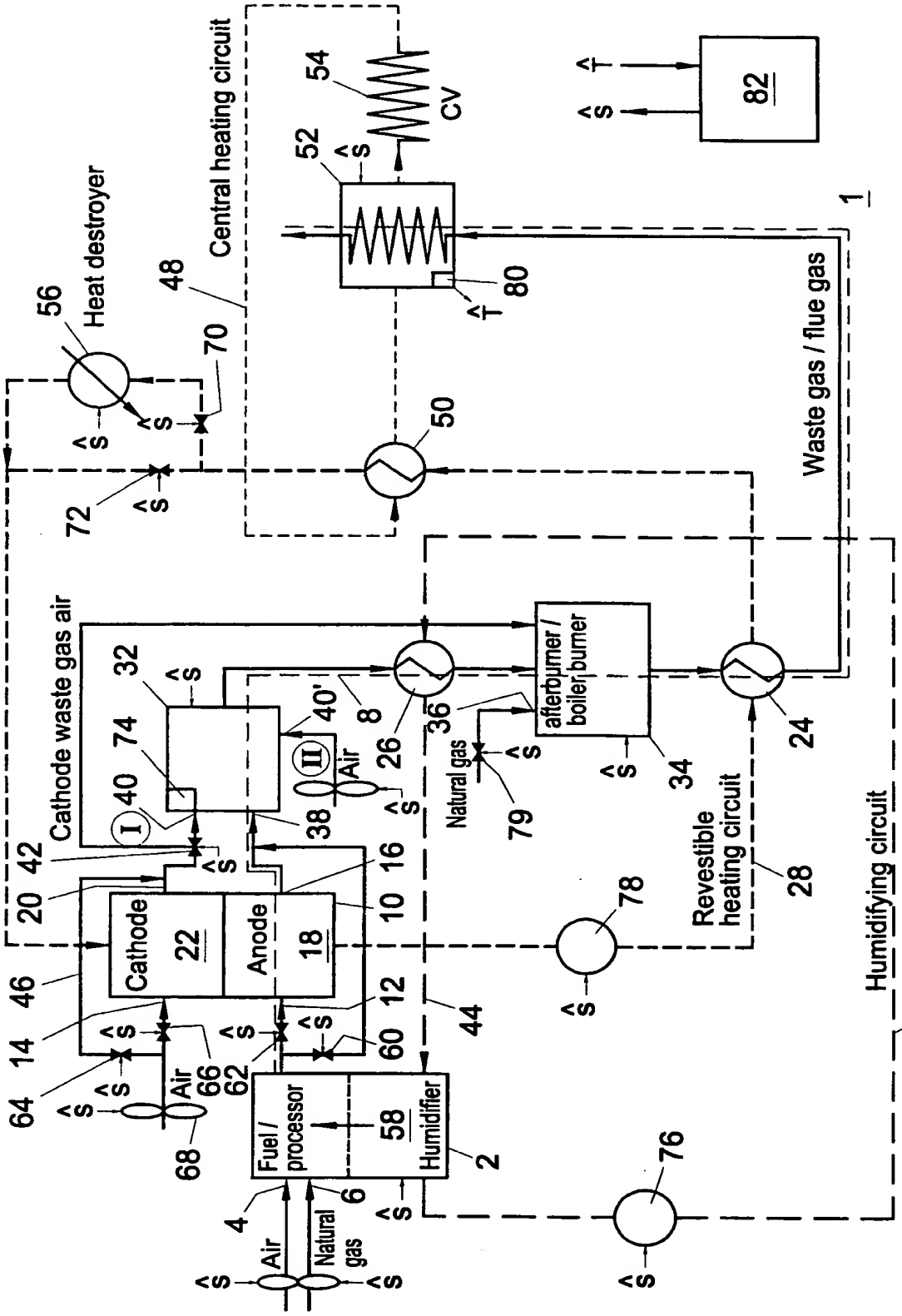
heat exchanger for exchanging heat between the first heating circuit and the central heating circuit.

15. A system according to claim 14, characterized in that the central heating circuit is provided with a heat exchanger included in the combustion path downstream of the first heat exchanger.

16. A system according to claim 14 or 15, characterized in that the first heating circuit is designed as a reversible heating circuit in which a heat transport medium can be selectively pumped round in two directions.

17. A system according to claim 14, 15 or 16, characterized in that the system is further provided with a heat destroyer in the form of, for instance, a fin included in the first heating circuit between the fuel cell and the third heat exchanger for adjustably discharging heat from the first heating circuit when the fuel cell, in use, cannot be cooled sufficiently after starting up.

18. A system according to any one of the preceding claims, characterized in that the fuel processor is provided with humidifying means for humidifying the hydrocarbons supplied to the fuel processor, which humidifier is included in the second heat exchanger for supplying heat to the humidifying means.


Central heating circuit
Heat destroyer
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Waste gas / flue gas
Cathode waste gas air
afterburner / boiler burner
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Revestible heating circuit
Humidifying circuit
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FIG. 1

INTERNATIONAL SEARCH REPORT

Ir Application No
PCT/NL 00/00365

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01M8/06 H01M8/04 F24D12/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 439 (E-827), 3 October 1989 (1989-10-03) -& JP 01 167960 A (MITSUBISHI ELECTRIC CORP), 3 July 1989 (1989-07-03) abstract	1,2,6,8, 9,14
A	DE 197 41 331 A (KERNFORSCHUNGSANLAGE JUELICH) 1 April 1999 (1999-04-01) page 4, line 8 - line 12; figure 1	1,2,5-9
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 September 2000	29/09/2000

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Application No
PCT/NL 00/00365

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Abstract of disclosure

The apparatus (1) comprises a cell block (1') with fuel cells (10), a heat insulating jacket (2), an afterburner chamber (12) between the jacket and the cell block, a prereformer (3) for a combustion gas (39') as well as an auxiliary heat source. The method comprises a start-up phase and a current-delivering operating state. Hot combustion gases (50") which are fed into the apparatus or are produced there in an auxiliary burner (5) form the auxiliary heat source during the start-up phase. The apparatus comprises a first and a second heat exchanger (6, 7) for the preheating of air (20') and for preheating the prereformer respectively. During the start-up phase air which is fed into the apparatus is preheated in the first heat exchanger (6) by means of a mixture formed of hot combustion gas and exhaust air (120') with the mixture being conducted separately from the air. Heat is supplied to the fuel cells with the preheated air. The exhaust air emerging from the cells is admixed to the hot combustion gas. In the second heat exchanger the prereformer is heated to the operating temperature with the hot combustion gas.

(Fig. 1)

P/00/011 28/5/91
Regulation 3.2(2)

AUSTRALIA

Patents Act 1990

ORIGINAL
COMPLETE SPECIFICATION
STANDARD PATENT

Application Number:

Lodged:

Invention Title: METHOD FOR OPERATING AN APPARATUS WITH FUEL CELLS

The following statement is a full description of this invention, including the best method of performing it known to us :-

P.6739 Ehph

Sulzer Hexis AG, Winterthur, Switzerland

Method for operating an apparatus with fuel cells

The invention relates to a method for operating an apparatus with fuel cells in accordance with the preamble of claim 1 as well as to an apparatus with which the method can be carried out.

A prereformer is integrated into an apparatus of this kind which is known from EP-A 0654 838. During the start-up phase an auxiliary burner is used to heat up the prereformer on the one hand and the infed air is preheated in a channel system in the jacket on the other hand. Heat is supplied to the cell block with the preheated air. This supply of heat is not sufficient to heat the fuel cells to a minimum operating temperature of 850°C. It is therefore necessary to feed combustion gas and air into the apparatus and allow it to burn in the afterburner chamber between the cell block and the jacket. Immediately after the beginning of the combustion, which must be ignited, large temperature gradients arise, through which the cells can be damaged.

The object of the invention is to provide a method for an apparatus with fuel cells as well as to provide a corresponding apparatus in which the cells remain undamaged during the start-up phase. This object is satisfied by the method and the apparatus defined in the independent claims 1 and 9.

The apparatus comprises a cell block with fuel cells, a heat insulating jacket, an afterburner chamber between the jacket and the cell block, a prereformer for a combustion gas as well as an auxiliary heat source. The method comprises a start-up phase and a current delivering operating state. Hot combustion gases which are fed into the apparatus or are produced there in an auxiliary burner form the auxiliary heat source during the start-up phase.

The apparatus in accordance with the invention contains a first and a second heat exchanger for the preheating of air and for the preheating of the prereformer respectively. The prereformer is arranged outside the cell block. It is advantageous to arrange the prereformer at the centre of the second heat exchanger and the first heat exchanger concentrically about the second. With this arrangement a ring gap in the second heat exchanger produces a connection between the afterburner chamber and the first heat exchanger.

In accordance with the invention, air which is supplied to the apparatus is preheated in the first heat exchanger during the start-up phase by means of a mixture of the hot combustion gas and exhaust air, the mixture being conducted separately from the air. Heat is supplied to the fuel cells with the preheated air. The exhaust air leaving the cells is admixed to the hot combustion gas. In the second heat exchanger the prereformer is heated up to the operating temperature with the hot combustion gas. During the operating state the exhaust gas leaving the afterburner chamber is used in the second heat exchanger as a heat source for the prereformer.

The dependent claims 2 to 8 relate to advantageous embodiments of the method in accordance with the invention. The dependent claims 10 to 12 relate to exemplary embodiments of the apparatus in accordance with the invention.

The invention will be explained in the following with reference to the drawings. Shown are:

Fig. 1 a vertical longitudinal section through the apparatus in accordance with the invention,

Fig. 2 an enlarged section of the same apparatus,

Fig. 3 a diagram for explaining the method in accordance with the invention,

Fig. 4 a schematic representation of a plant in which a heating system forms a combination with the apparatus of the invention,

Fig. 5 a detail of the second exemplary embodiment of the apparatus in accordance with the invention, and

Fig. 6 a section as in Fig. 2 for a third exemplary embodiment.

The apparatus 1 in Fig. 1 comprises a cell block 1' with fuel cells 10 in an upper part 11, a part of a heat insulating jacket 2, an afterburner chamber 12 and a supply point 20 for air 20'. The air 20' enters via a channel system 21, 22 and a wall 26 permeable to air into a ring-gap-shaped chamber 23, from which it is fed into the individual cells via tubelets 12'. Combustion gas can be

supplied to the cell block 1' from a lower part 15 of the apparatus 1 via a central tube 13. The jacket 2, with an outer skin 24 and heat insulating walls 25, 25' and 26, is formed in such a manner that it acts as a preheater for the infed air 20'.

The lower part 15 of the apparatus 1 – see also Fig. 2 – comprises, in addition to a part of the jacket 2, a prereformer 3, a sulphur absorber 3', an auxiliary burner 5, a first heat exchanger 6 and a second heat exchanger 7. Both the prereformer 3 and the sulphur absorber 3' have a cylindrical form. A jacket chamber 4 around the absorber 3' has the shape of a ring-gap and is executed as a vaporiser for water 40' (supply line 40). The auxiliary burner 5 is arranged in a ring space 67. It is executed as a toroidal chamber 51 which is closed off upwardly by a porous plate 52. A gas / air mixture 50' (supply line 50) is brought to combustion on this plate 52 with uniformly distributed passage openings, with an areally spread flame 55 – see Fig. 2 – forming.

The combustion gas 30' required for the current delivering reaction – generally natural gas is used – is conducted via the line 30 into the absorber 3', which is provided for the removal of impurities of the gas 50' which contain sulphur. Subsequently methane, which is contained in the gas 50', is converted in the prereformer 3 together with water into hydrogen and carbon monoxide. The energy required for this reaction is supplied during the current delivering operating state by the hot exhaust gas 120" (see Fig. 2) which comes out of the afterburner chamber 12 and flows through the second heat exchanger 7.

During the start-up phase the energy for heating the prereformer 3 is supplied by the auxiliary burner 5. The

combustion gas 50" of the auxiliary burner 5 heats up the wall 72 of the second heat exchanger 7. The heat transport from the wall 72 to the inner wall 71, which is in heat-conducting contact with the prereformer 3, proceeds mainly through radiation, with the temperature difference between the two walls 71 and 72 amounting to about 100°C.

The combustion gas 50" of the auxiliary burner 5 flows radially outwards and is mixed with exhaust air 120' from the cell block 1' between the points F and G (see Fig. 2). The gas mixture 60' flows between the cylindrical walls 61 and 62 of the first heat exchanger 6 to an outlet point 60 where the partially cooled gas mixture 60' leaves the apparatus 1. The air supplied into the apparatus 1 flows along the wall 61 in counterflow to the gas mixture 60' and is thereupon heated from a temperature which lies only insubstantially above ambient temperature (i.e. about 20 to 30°C) to a temperature between 700 to 800°C. Heat is supplied to the fuel cells 10 with the preheated air 20'. The exhaust air 120' leaving the cells 10 flows through the second heat exchanger 7 and is subsequently – as already mentioned – mixed with the combustion gases 50" of the auxiliary burner 5.

After the prereformer and the cells have been warmed up to temperatures at which a current delivering operation can set in, the amounts of infed air 20' and combustion gas 30' are brought to values which correspond to a stationary operating state; the supply of the gas / air mixture 50' into the auxiliary burner 5 is discontinued. This happens when the cells have reached a temperature of about 800°C, i.e. when the temperature in the afterburner chamber 12 exceeds a value at which the spontaneous combustion of the gas leaving the cells – with air leaving simultaneously – commences.

Fig. 2 shows the points A, B, ... H in the channel system of the jacket 2. The indirect heat transfer from the hot gas mixture 60' to the infed air 20' takes place between the points A and B, and G and H respectively. Between C and D the exhaust air 120' or the hot exhaust gas 120" respectively gives off heat to the prereformer 3; between D and E it gives off heat to the water vaporiser 4 as well as to the sulphur absorber 3'. Between F and G the exhaust air 120' is mixed with the hot combustion gas 50" during the start-up phase.

The diagram of Fig. 3 shows in a simplified manner the course of the temperatures in the channel system of the jacket 2, with the diagram points A1, B1 ... showing the temperatures for the stationary operating state at the named points A, B, ..., and the diagram points A2, B2 ... correspondingly showing the temperatures passed through during the start-up phase. The points A, B, ... are plotted on the x-axis, where the distances between these points, however, do not correspond to the actual distances in the apparatus 1. The upwardly directed arrows in the diagram show that the points C2, ... F2 are displaced upwards in the course of the start-up phase so that they come to lie at the points C1, ... F1. The point G2' corresponds to the mixture temperature that results on mixing the hot combustion gas 50" with the exhaust air 120'. The values (0 - 1000°C) that can be read off on the T-axis for the diagram points A1, B1, ... A2, B2, ... correspond substantially to the actual temperatures. For the sake of simplicity the points C2 and D2 in the diagram are plotted on the linear connection between the points B2 and E2. The same holds for the point D1 on the connection between C1 and E1.

During the start-up phase it is advantageous to provide a slight gas supply into the cell block 1' in order that the gas spaces in the fuel cells 10 are flushed and in order that no air can enter into them. The flushing gas mixes with the exhaust air in the afterburner chamber 12 without a combustion taking place there prior to the ignition temperature being reached. A combustion can be ignited by means of ignition electrodes 81 and 82 beneath the cell block 1' so that the flushing gas is burned in the ring gap chamber 70 and the resulting heat can be taken up by the prereformer 3 as well as by the absorber 3'.

The further development of the materials for fuel cells will presumably lead to the operation already being performable at temperatures between 600 and 700°C in the future instead of between 850 and 900°C. The teaching disclosed here can of course also be applied in corresponding apparatuses with lower operating temperatures.

The auxiliary heat source required for the start-up phase need not be produced by the auxiliary burner 5. It is also possible to form the auxiliary heat source with hot combustion gases from an external burner 9 – see Fig. 4.

The apparatus shown schematically in Fig. 4 shows, in addition to the apparatus 1 in accordance with the invention and the burner 9, a heat exchanger 95 as well as a heat consumer 99, for example a room heating system. Gas 30" is burned with air 20" in the burner 9 to form the combustion gas 90".

Using the member 90, the combustion gas 90" can be selectively supplied to the heat exchanger 95 (gas flow 90') or to the apparatus 1 (gas flow 50") through the

connecting stub 50. The hot combustion gas 50" can be fed into the lower part 15 of the apparatus 1 in a manner similar to the gas / air mixture 50' via a torus-shaped distributor body (corresponding to the auxiliary burner 5 in Fig. 1).

In addition the heat exchanger 95 can also be used for utilising the exhaust heat set free from the apparatus 1 with the hot exhaust gas 60'. The heat won in the heat exchanger 95 is supplied to the consumer 99 via the line 98. The gas flow 95' with the cooled gases is conducted into a non-illustrated chimney.

Fig. 4 shows in addition that the electrical direct current produced in the upper part 11 of the apparatus 1 from the gas 30', the water 40' and the air 20' is converted into an alternating current in a converter 8.

Fig. 5 shows a detail of an exemplary embodiment in which the conduction of the hot combustion gas 50", and accordingly the second heat exchanger 7, have been modified. Instead of radially outwards, the gas 50" first flows towards the centre and into the heat exchanger 7, where it is mixed with the exhaust air 120'. In this embodiment the heat exchange takes place from the hot gas 50" into the prereformer 3 via only one wall, namely the wall 71.

In the third exemplary embodiment of Fig. 6 a channel system comprising three concentric ring gap spaces 70, 76 and 67 adjoins and follows the afterburner chamber 12. The auxiliary burner 5 is arranged at the transition from the inner ring gap space 70 to the middle ring gap space 76 and it borders on the outer surface of the apparatus 1, i.e. is disposed adjacent the outer surface of the apparatus. The

outer ring gap space 67 belongs to the first h at exchanger 6, whereas the other two form parts of the second heat exchang r 7. In comparison with the first two exemplary embodiments the third one represents a simpler construction, since the first heat exchanger 6 comprises only one ring gap space 67 on the exhaust gas side and thus the wall 61 is omitted. The arrangement of the auxiliary burner 5 at the outer surface of the apparatus 1 is particularly advantageous since the gas mixture supplied via the line 50 is less strongly heated by the hot exhaust gas 120', 120" and thus the danger of a spontaneous combustion in the space 51 is less great.

"Comprises" (or grammatical variations thereof) when used in this specification is to be taken as specifying the stated features, integers, steps, or components but does not preclude the addition of one or more other features, integers, steps, or components or groups thereof.

P.6739 Ehph

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Method for operating an apparatus (1) with fuel cells (10) which comprises a cell block (1'), a heat insulating jacket (2), an afterburner chamber (12) between the jacket and the cell block, a prereformer (3) for a combustion gas (30') as well as an auxiliary heat source, wherein the method comprises a start-up phase and a current-delivering operating state, and wherein hot combustion gases (50") which are fed into the apparatus or are produced there in an auxiliary burner (5) form the auxiliary heat source during the start-up phase,

characterised in that during the start-up phase air (20') that is supplied to the apparatus is preheated in a first heat exchanger (6) by means of a mixture (60') of the hot combustion gas (50") and exhaust air (120') with the mixture being conducted separately from the air; in that heat is supplied to the fuel cells with the preheated air; in that the exhaust air emerging from the cells is admixed to the hot combustion gas; in that the prereformer is heated to operating temperature with the hot combustion gas (50") in the second heat exchanger (7); and in that during the operating state the exhaust gas (120") leaving the afterburner chamber is used in the second heat exchanger as a source of heat for the prereformer.

2. Method in accordance with claim 1 characterised in that during the start-up phase the heat transfer from the hot combustion gas (50") to the prereformer (3) taking place in the second heat exchanger (7) takes

place via a ring gap (70) through which the exhaust air (120') flowing out of the cell block (1') and through the afterburner chamber (12) is conducted into the first heat exchanger (6).

3. Method in accordance with claim 1 or claim 2 characterised in that after the prereformer (3) and the cells (10) have been heated to temperatures at which a current delivering operation can set in, the amounts of infed air (20') and gas (30') are brought to values which correspond to a stationary operating state; and in that the heat supply of the auxiliary heat source (50") is discontinued.

4. Method in accordance with one of the claims 1 to 3 characterised in that the heat supply of the auxiliary heat source (50") is discontinued when the cells (10) have attained a temperature of about 800°C.

5. Method in accordance with one of the claims 1 to 4 characterised in that the amounts of infed air (20') and gas (30') are brought to values which correspond to a stationary operating state, and this at a time when the temperature in the afterburner chamber exceeds a value at which the spontaneous combustion of the air / gas mixture sets in.

6. Method in accordance with one of the claims 1 to 5 characterised in that at the beginning of the start-up operation the infed air (20') is preheated from about 20 to 30°C to about 700 to 800°C in the first heat exchanger (6), with the indirect heat exchange between the mixture of hot combustion gas (50") and exhaust air (120') being performed in counterflow.

7. Method in accordance with one of the claims 1 to 6 characterised in that the prereformer (3) is arranged outside the cell block (1') and in the centre of the second heat exchanger (7); and in that during the current-delivering operating state the exhaust gases (120") flowing out of the afterburner chamber (12) into the second heat exchanger supply the prereformer (3) with heat through a flow directed radially inwards.

8. Method in accordance with claim 7 characterised in that the first heat exchanger (6) is arranged concentrically about the second (7); and in that the hot combustion gas (50") is formed in or fed into a ring space (67) between the two heat exchangers.

9. Apparatus (1) with fuel cells (10) for carrying out the method in accordance with one of the claims 1 to 8, which apparatus comprises a cell block (1'), a heat insulating jacket (2), an afterburner chamber (12) between the jacket and the cell block, a prereformer (3) for combustion gas (30'), an internal or external auxiliary burner (5, 9) for producing an auxiliary heat source for the start-up phase and a first and a second heat exchanger (6, 7) for the preheating of air (20') and for preheating the prereformer respectively, characterised in that the prereformer is arranged outside the cell block and at the centre of the second heat exchanger (7); in that the first heat exchanger (6) is arranged concentrically about the second; and in that a ring gap (70) arranged in the second heat exchanger produces a connection between the afterburner chamber and the first heat exchanger.

10. Apparatus in accordance with claim 9 characterised in that the internal auxiliary burner (5) comprises a ring-shaped combustion surface (52) and is arranged between the first and second heat exchangers (6, 7).

11. Apparatus in accordance with claim 9 characterised in that a ring-shaped chamber (51, 67) is arranged between the first and the second heat exchangers (6, 7) into which hot combustion gases (50") can be fed which are produced with the external auxiliary burner (9).

12. Apparatus in accordance with one of the claims 9 to 11 characterised in that the cell block (1') is built up of a cylindrical stack of fuel cells (10); and in that the afterburner chamber (12) surrounds the stack in the form of a ring gap.

13. Apparatus in accordance with claims 10 and 11 characterised in that a channel system comprising three concentric ring gap spaces (70, 76, 67) adjoins and follows the afterburner chamber (12); in that the auxiliary burner (5) is arranged at the transition from the inner ring gap space (70) to the middle ring gap spaces (76); and in that the auxiliary burner borders on the outer surface of the apparatus (1).

DATED this 17th day of June 1997.

SULZER HEXIS AG

WATERMARK PATENT & TRADEMARK ATTORNEYS
290 BURWOOD ROAD
HAWTHORN. VIC. 3122.

24945/97

Fig.1

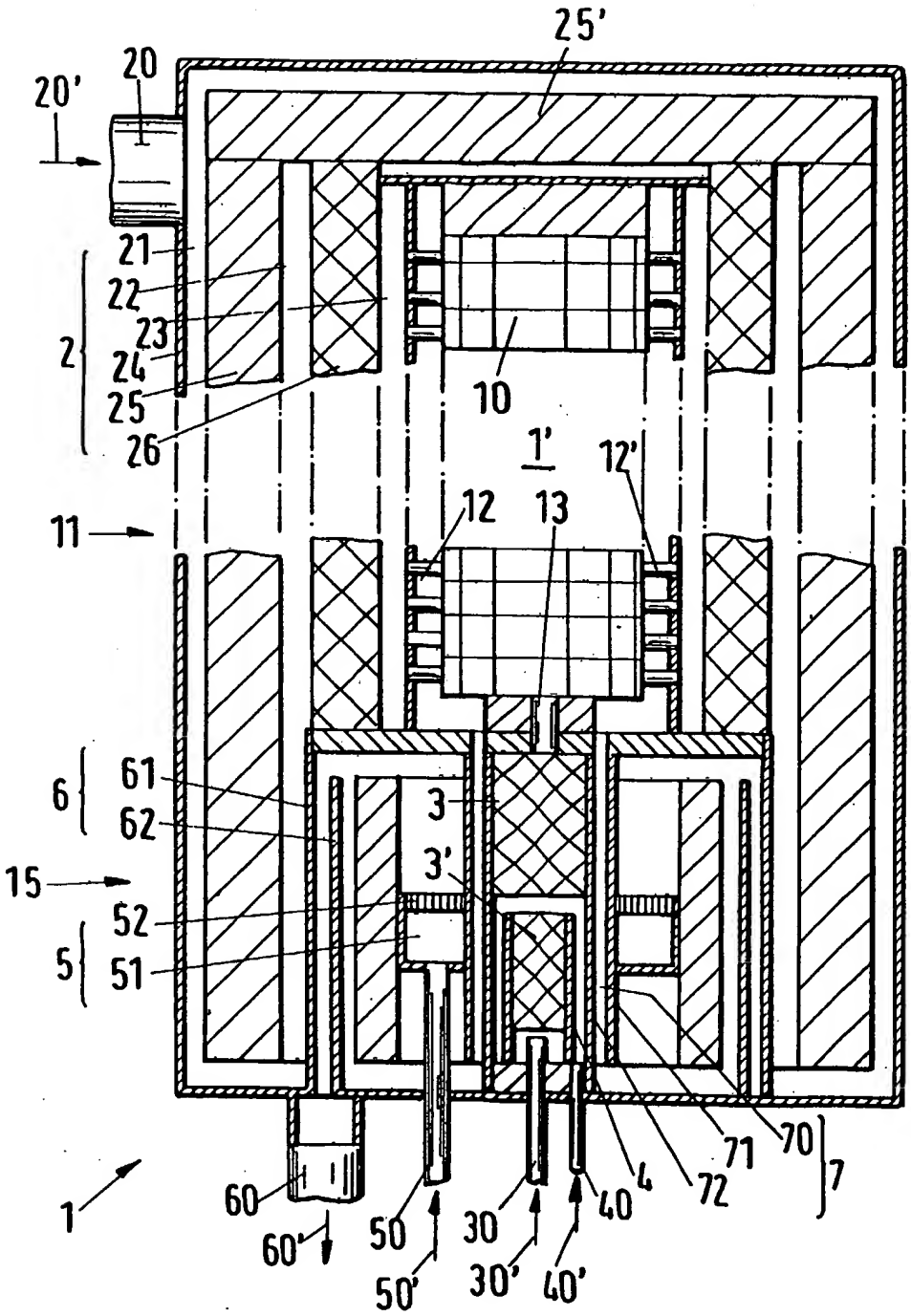
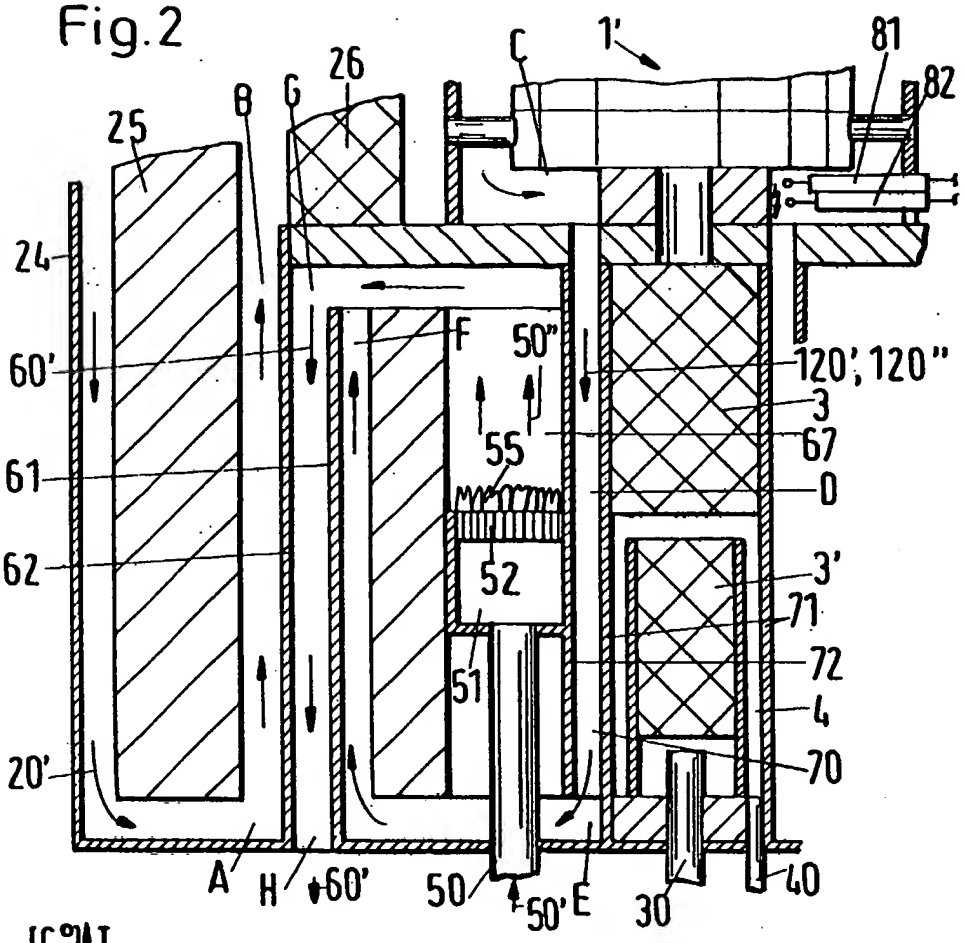


Fig.2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3
67
D
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71
72
4
70
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A
H
60'
50
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E
30

Fig.3

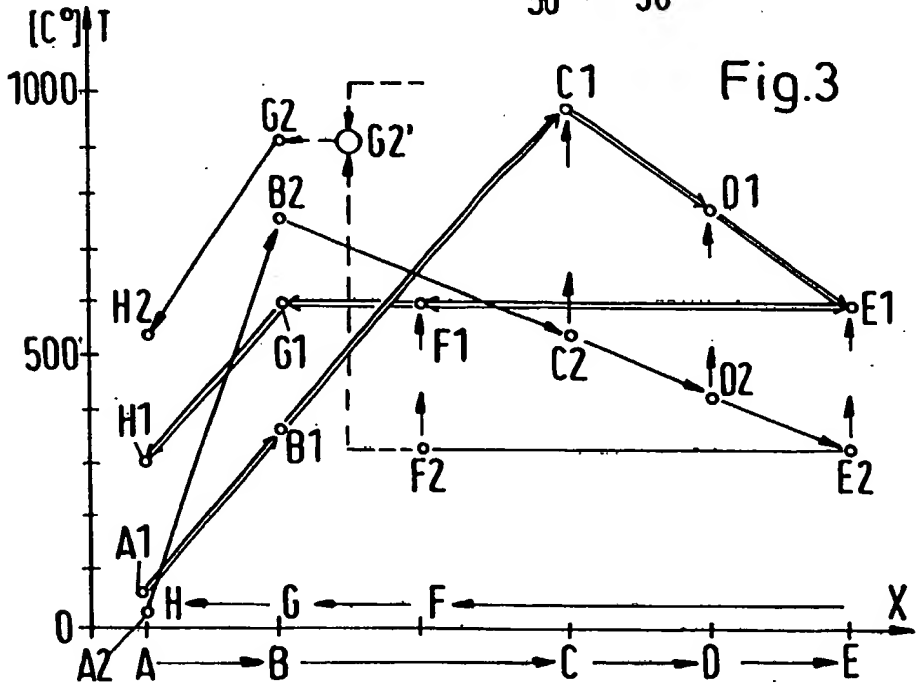
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Fig. 4

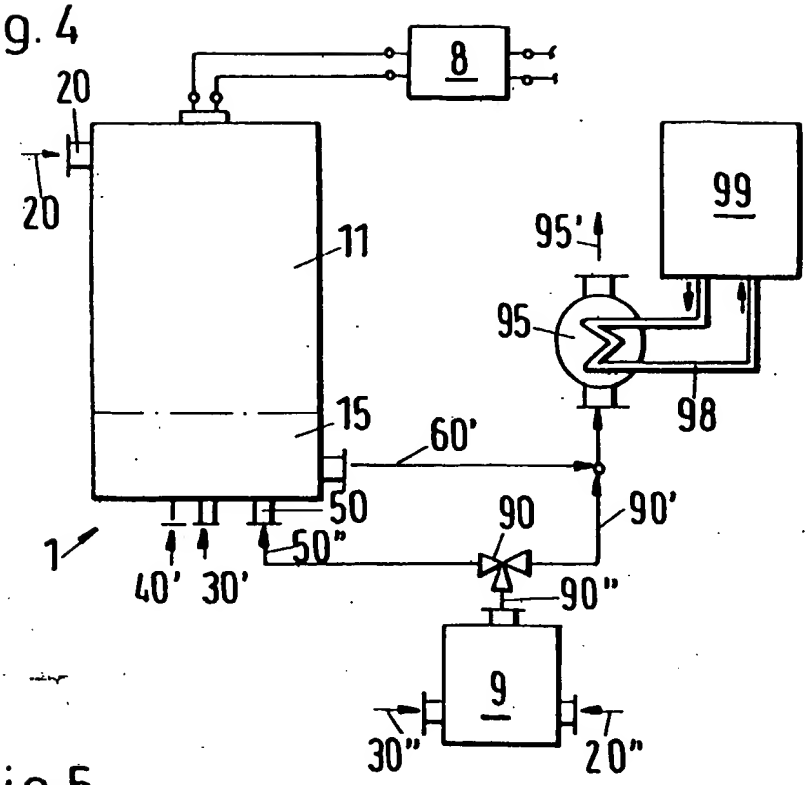
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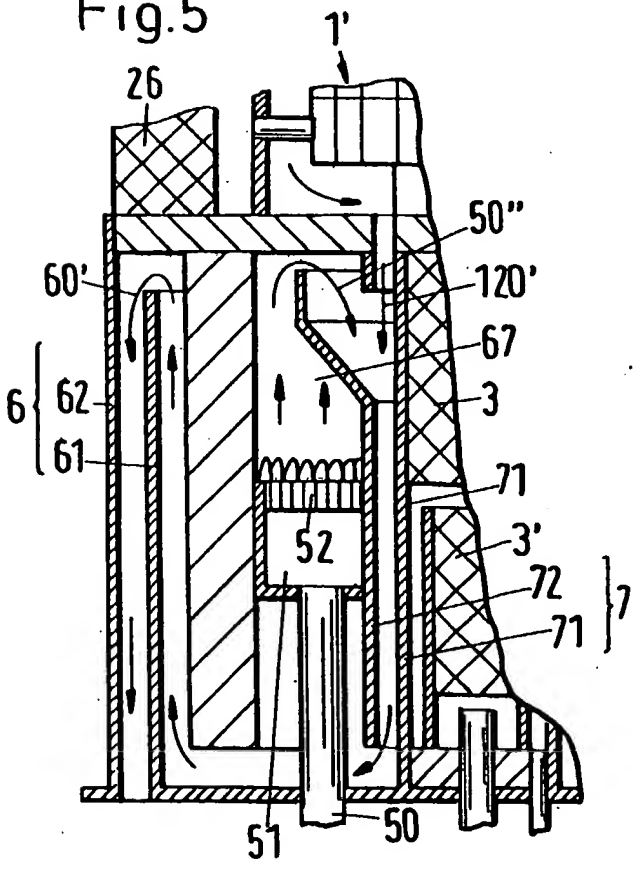
Fig. 5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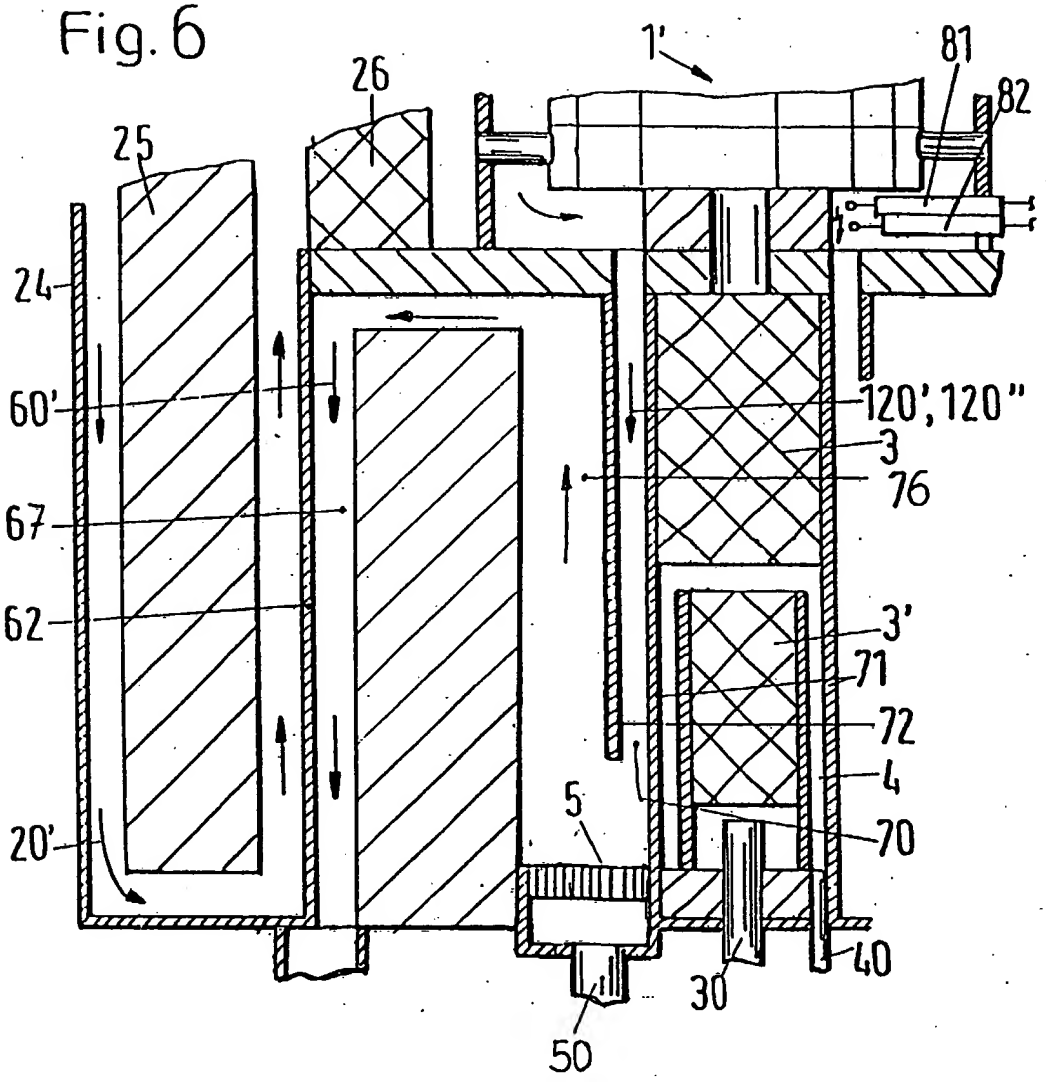
72
7
71
51
50

Fig. 6



P ENT COOPERATION TREA

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 13 February 2001 (13.02.01)	
International application No. PCT/NL00/00365	**Applicant's or agent's file reference** P51344PC00
International filing date (day/month/year) 26 May 2000 (26.05.00)	**Priority date** (day/month/year) 27 May 1999 (27.05.99)
Applicant SCHOLTEN, Anton et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

22 December 2000 (22.12.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Zakaria EL KHODARY
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

14

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P51344PC00		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/NL00/00365	26/05/2000	27/05/1999
International Patent Classification (IPC) or national classification and IPC H01M8/06		
Applicant PLUG POWER INC. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22/12/2000	27.07.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Wiedemann, E Telephone No. +49 89 2399 7542

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/NL00/00365

I. Basis f th rep rt

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-11 as originally filed

Claims, No.:

1-18 as originally filed

Drawings, sheets:

1 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	5-7, 9-13, 15-17
	No:	Claims	1-4, 8, 14, 18
Inventive step (IS)	Yes:	Claims	5-7, 9-13, 15-16
	No:	Claims	1-4, 8, 14, 17, 18
Industrial applicability (IA)	Yes:	Claims	1-18
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
s e separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive st p or industrial applicability; citations and explanations supporting such statement

1) Documents

D1: PATENT ABSTRACTS OF JAPAN vol. 013, no. 439 (E-827), 3 October 1989 (1989-10-03) -& JP 01 167960 A (MITSUBISHI ELECTRIC CORP), 3 July 1989 (1989-07-03)

D2: DE 197 41 331 A (KERNFORSCHUNGSANLAGE JUELICH) 1 April 1999 (1999-04-01)

D3: DE 197 31 642 C (DBB FUEL CELL ENGINES GMBH) 18 February 1999 (1999-02-18)

D4: WO 95 06842 A (AQUA CHEM INC) 9 March 1995 (1995-03-09)

D5: PATENT ABSTRACTS OF JAPAN vol. 1999, no. 02, 26 February 1999 (1999-02-26) -& JP 10 308230 A (NIPPON TELEGR &TELEPH CORP <NTT>), 17 November 1998 (1998-11-17)

D6: PATENT ABSTRACTS OF JAPAN vol. 018, no. 658 (E-1643), 13 December 1994 (1994-12-13) -& JP 06 260196 A (FUJI ELECTRIC CO LTD), 16 September 1994 (1994-09-16)

D7: EP-A-0 951 087 (ISHIKAWAJIMA HARIMA HEAVY IND) 20 October 1999 (1999-10-20)

D8: EP 0814526 A, Sulzer Hexis AG, R. Diethelm, Published 29.12.1997

Cited by the examiner, copy attached, and a copy of the corresponding US Patent: US 5998053.

2) Novelty

The subject-matter of claims 1-4, 8, 14 and 18 is not novel in the sense of Article 33 (1) and (2) PCT for the following reasons:

Document **D8** discloses a system containing a reformer for producing hydrogen which is passed along a path to the fuel cells. The combustion gases of the fuel cells are passed along this path to an afterburner. Furthermore, a first and second heat exchanger and an auxiliary burner are part of the system (Column 1, Line 29ff). Document **D8** further discloses how the fuel cells and the reformer are preheated in the start-up phase and how the system is switched to steady-state conditions (Column 1, Line 29ff).

The two heat exchangers are connected in series in the circuit. A first circuit containing the fuel cell and a second circuit containing the reformer are disclosed (Column 2, Line 31- Column 3, Line 54).
The auxiliary burner is installed to heat up the reformer in the start-up phase. The afterburner (or waste gas burner) is included into the combustion gas stream between the fuel cell and the second heat exchanger (Column 1, Line 55 - Column 2, Line 2). This burner is also placed between the first and second heat exchanger (Column 2, Line 30 - Column 3, Line 41). The fuel cells are equipped with two inlets, one for air and the second one for the hydrogen processed by the reformer and implicitly two outlets for the combustion gases of the anode and cathode (see Fig. 1). **D8** discloses humidifying means in which a water reservoir is heated by the combustion gases of the fuel cells (Fig. 2, Column 3, Line 55 - Column 4, Line 5).
Therefore, the subject-matter of claims 1-4, 8, 14 and 18 is not allowable, Article 33 (1) and (2) PCT.

Document **D1** discloses a methanol fuel cell which is equipped with a cooling circuit containing a cooling medium to maintain a certain working temperature of the fuel cell and of the reformer to optimize the energy efficiency. A controlling unit for measuring the temperature and for controlling the flow of the cooling medium is as well disclosed. Therefore, this document is not considered to be relevant for the present application.

Document **D2** discloses a cooling unit for a fuel cell. The supply gases are lead into a liquid trap, the liquid vaporizes by cooling and humidifying the supply gases. This protects the fuel cell of local over heating and increases the cycle time of the apparatus.
Therefore, this document is not considered to be relevant for the present application.

Document **D3** discloses a fuel cell for producing electrical energy to power a car. Regarding the energy efficiency of the system the invention recovers the braking energy without implementing a second energy storage system. The recovered energy is used for the electrical installation of the car or to feed a compressor to compress burning gases. Therefore, this document is not considered to be relevant for the present application.

Document **D4** discloses a fuel cell linked to a boiler and a cooling circuit. The cooling water circuit of the fuel cell transfers heat to the boiler feedwater to preheat the water. The boiler

converts the preheated water into steam to feed a steam or hot water facility. This steam then condensates and is returned to the fuel cell to be preheated again.
Therefore, this document is not considered to be relevant for the present application.

Document **D5** discloses a system of mixing fuel gas and air, to desulphurise it and to reform it for the fuel cell. The fuel cell is also fed directly by air for oxidizing process and the exhaust gases of the fuel cell are burnt afterwards in a waste gas burner. The cooling circuit contains the cooling of the reformer directly linked to the boiler where steam is generated from the cooling water.
Therefore, this document is not considered to be relevant for the present application.

Document **D6** discloses a fuel cell in which the cooling circuit is used as a heating circuit during the start-up phase. The difference to the present application is the lack of a second heat exchanger and a waste gas burner.
Therefore, this document is not considered to be relevant for the present application.

Document **D7** discloses a fuel cell in which the air supplied to the cathode is compressed before by a compressor. This compressor is driven by an exhaust gas turbine operating with the anode exhaust gas. Therefore, this document is not considered to be relevant for the present application.

3) Inventive Step
The technical problem underlying the present invention is to supply heat to the fuel processor and the fuel cell during the start up phase.
The subject-matter of claims 1-4, 8, 14 and 18 is not based on an inventive step, Article 33 (3) PCT, because of the above mentioned reasons (point 2) Novelty).
The subject-matter of claim 17 does not solve the above mentioned technical problem of the present invention and adds only another technical feature to the heat exchange circuit and to its important technical features linked with the above mentioned problem.
Therefore, the subject-matter of claim 17 is not considered to be based on an inventive step, Article 33 (3) PCT.

The subject-matter of claims 5-7, 9-13, 15 and 16 is considered as being novel and

inventive:

-The bypass bridging of inlets and outlets to start a combustion process to heat up the whole system.

-A central heating unit linked to fuel cell system is state of the art but the way how the central heating unit is linked with help of a third heat exchanger to the first heat exchanger of the fuel cell system is not obvious.

-To pump a heat transport medium into two directions depending on the working mode of the fuel cell system is not disclosed in the prior art or even obvious.

4) Industrial Applicability

The subject-matter claimed in claims 1-18 is industrially applicable in the field of fuel cells for generating energy, e.g. for a house.

Re Item VII

Certain defects in the international application

The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

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For receiving Office use only

International Application No. PCT/NL 00 / 00365

International Filing Date 26 MAY 2000 (26.05.00)

BUREAU VOOR DE INDUSTRIËLE EIGENDOM
P.C.T. INTERNATIONAL APPLICATION

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* P51344PC00

Box No. I TITLE OF INVENTION

System for generating electric energy and heat

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

Plug Power Inc.
968 Albany-Shaker Road
Latham, New York 12110
United States of America

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: US

State *(that is, country)* of residence: US

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

Scholten, Anton
Henriette van Eijklaan 36
7321 LE Apeldoorn
The Netherlands

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: NL

State *(that is, country)* of residence: NL

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Mr Ir A.W. Prins, c.s.

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2587 BN The Hague
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Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

van Nisselrooij, Petrus Franciscus Maria Theresia
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This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: NL

State *(that is, country)* of residence: NL

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
- ☒ the United States of America only
- ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

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Verdistraat 29
7391 SJ Twello
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This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: NL

State *(that is, country)* of residence: NL

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
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Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

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The Netherlands

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: DE

State *(that is, country)* of residence: NL

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
- ☒ the United States of America only
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Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of:
- ☐ all designated States
- ☐ all designated States except the United States of America
- ☐ the United States of America only
- ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box N .V DESIGNATION OF STATES

The following designati ns are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

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☒ **EP** **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA** **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

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☒ **BA** Bosnia and Herzegovina .....
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☒ **MN** Mongolia
☒ **MW** Malawi .....
☒ **MX** Mexico .....
☒ **NO** Norway
☒ **NZ** New Zealand .....
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☒ **PT** Portugal .....
☒ **RO** Romania
☒ **RU** Russian Federation .....
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☒ **SK** Slovakia .....
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☒ **UA** Ukraine .....
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☒ **YU** Yugoslavia .....
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Check-b xes reserved f r designating States which have become party to the PCT after issuance of this sheet:

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Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Sheet No. 4

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) (27-05-99) 27 May 1999	1012162	NL		
item (2) (03.11.99) 3 November 1999	1013474	NL		
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s) 1 / 2

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)*: ISA / EP

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority)*: Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	: 4
description (excluding sequence listing part)	: 13
claims	: 3
abstract	: 1
drawings	: 1
sequence listing part of description	:
Total number of sheets	: 22

This international application is **accompanied by** the item(s) marked below:

1. ☒ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological materia
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*:

Figure of the drawings which should accompany the abstract:

Language of filing of the international application: English

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

For receiving Office use only

1. Date of actual receipt of the purported international application: 26 MAY 2000 (26.05.00)
2. Drawings: ☒ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA /
6. ☐ Transmittal of search copy delayed until search fee is paid.

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Date of receipt of the record copy by the International Bureau: 28 JUNE 2000 (28.06.00)

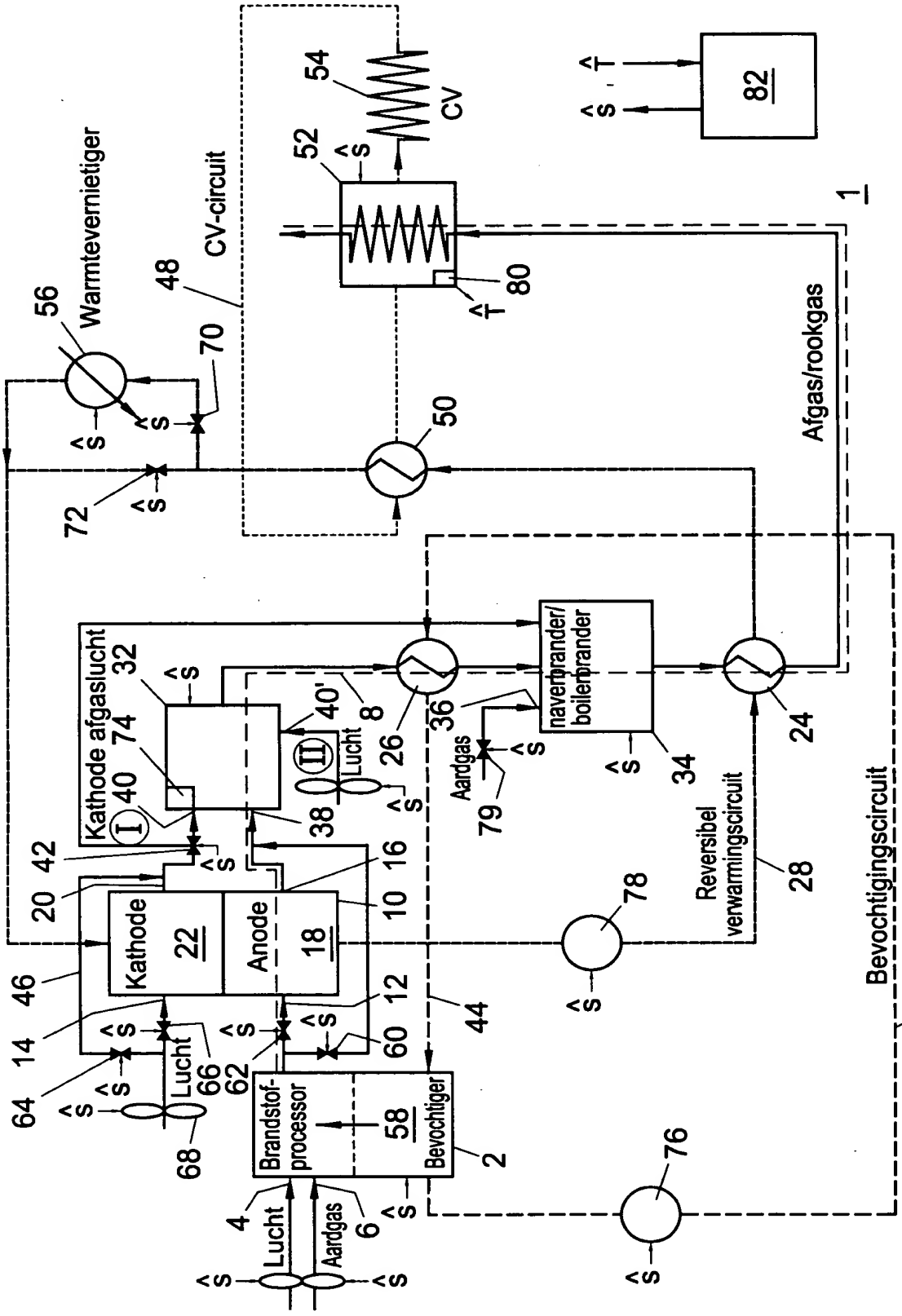
82
CV
54
52
CV-circuit
48
Warmtevernietiger
56
70
72
50
80
1
Afgas/rookgas
Kathode afgaslucht
32
74
40
I
42
20
Kathode
22
Anode
18
16
10
46
14
64
66
62
60
12
44
68
Lucht
Brandstof-
processor
58
Bevochtiger
2
4
6
Lucht
Aardgas
40'
II
Lucht
38
8
26
36
naverbrander/
boilerbrander
34
Aardgas
79
24
Reversibel
verwarmingscircuit
28
78
76
Bevochtigingscircuit
30

FIG. 1

Titel: Systeem voor het genereren van elektrische energie en warmte.

De uitvinding heeft betrekking op een systeem voorzien van een brandstofprocessor voor het genereren van waterstof uit een koolwaterstofverbinding en een verbrandingstraject waarlangs de gegenereerde waterstof wordt geleid voor verbranding, waarbij in het verbrandingstraject tenminste een brandstofcel is opgenomen voor het tenminste opwekken van elektrische energie en eventueel warmte door verbranding van de door de brandstofprocessor gegenereerde waterstof.

Dergelijke systemen zijn op zich bekend. Bij deze bekende systemen wordt door middel van warmteuitwisseling de energieproductie van de brandstofcel geïntegreerd met de energiebehoefte van de brandstofprocessor, met name voor het genereren van stoom maar ook voor de toevoer van energie voor H_2 productie via de endotherme stoomreformingsreactie. Een dergelijk systeem is niet geschikt om bijvoorbeeld een gebouw of huis van een sterk wisselende hoeveelheid elektrische energie te voorzien. Ook is het systeem niet geschikt om autonoom op te starten. In vol bedrijf dient immers zowel de brandstofcel als de brandstofprocessor van warmte te zijn voorzien. Er zijn reeds methoden omschreven voor opstart van de brandstofcel met door een stationair opererende brandstofprocessor gegenereerde warmte. Het probleem bij deze methode is echter nog steeds dat de brandstofprocessor moet worden opgestart onder toevoer van warmte.

De onderhavige uitvinding heeft als doel om één systeem te verschaffen voor zowel de integratie van de energieproductie van de brandstofcel met de energiebehoefte van de brandstofprocessor, als ook voor de simultane opstart van de brandstofcel en de brandstofprocessor. Ook

dient het systeem aan een variabele energiebehoefte te kunnen voldoen.

Het systeem volgens de uitvinding is hiertoe gekenmerkt in dat het systeem verder is voorzien van een eerste warmtewisselaar en een tweede warmtewisselaar die enerzijds stroomafwaarts van de brandstofcel in serie in het verbrandingstraject zijn opgenomen, een eerste verwarmingscircuit waarin de brandstofcel is opgenomen en een tweede verwarmingscircuit waarin de brandstofprocessor is opgenomen waarbij de eerste warmtewisselaar anderzijds in het eerste verwarmingscircuit is opgenomen voor het uitwisselen van warmte tussen het verbrandingstraject en het eerste verwarmingscircuit en de tweede warmtewisselaar anderzijds in het tweede verwarmingscircuit is opgenomen voor het uitwisselen van warmte tussen het verbrandingstraject en het tweede verwarmingscircuit.

Dankzij het eerste en tweede verwarmingscircuit kunnen bij opstart respectievelijk de brandstofcel en de brandstofprocessor worden voorzien van warmte. In bedrijf kan het eerste verwarmingscircuit zelfs worden gebruikt voor het afvoeren van een overschot aan door de brandstofcel gegenereerde energie voor andere doeleinden zoals hierna nog nader zal worden uiteengezet.

In het bijzonder geldt dat het systeem verder is voorzien van een tussen de brandstofcel en de tweede warmtewisselaar in het verbrandingstraject opgenomen afgasbrander. Met behulp van de afgasbrander kan de nog niet volledig door de brandstofcel verbrande waterstof alsnog, althans nagenoeg, volledig worden verbrand.

Meer in het bijzonder geldt dat het systeem verder is voorzien van een tussen de eerste en tweede warmtewisselaar in het verbrandingstraject opgenomen brander, met de functie van naverbrander of boilerbrander.

Volgens de uitvinding kan de brander worden benut als naverbrander voor waterstof die ook door de afgasbrander nog niet volledig is verbrand.

In het bijzonder geldt dat de afgasbrander verder is voorzien van tenminste een eerste ingang die in het verbrandingstraject is opgenomen en een tweede ingang voor het toevoeren van lucht. Meer in het bijzonder geldt hierbij dat het systeem dusdanig is ingericht dat afgaslucht afkomstig van de brandstofcel of lucht van elders aan de afgasbrander kan worden toegevoerd. De brandstofcel is voorzien van een eerste ingang die met de brandstofprocessor is verbonden voor het toevoeren van de waterstof aan de brandstofcel, een tweede ingang voor het toevoeren van lucht aan de brandstofcel, een eerste uitgang voor het afvoeren van afgas van een anode van de brandstofcel en een tweede uitgang voor het afvoeren van afgaslucht van een kathode van de brandstofcel.

Hierbij geldt bij voorkeur dat de eerste uitgang van de brandstofcel met de in het verbrandingstraject opgenomen eerste ingang van de afgasbrander is verbonden. Hierbij kan de tweede uitgang van de brandstofcel met de brander zijn verbonden voor het toevoeren van afgaslucht van de brandstofcel aan de brander. Bij voorkeur geldt hierbij dat de tweede uitgang via een regelklep tevens met de tweede ingang van de afgasbrander is verbonden voor het toevoeren van afgaslucht aan de afgasbrander. Ook is het echter mogelijk een aparte luchttoevoer te gebruiken.

Volgens een geavanceerde uitvoeringsvorm van het systeem geldt dat het systeem verder is voorzien van een regelbare eerste bypass-verbinding voor het bij opstarten van het systeem overbruggen van de eerste ingang en de eerste uitgang van de brandstofcel. Hierbij geldt bij voorkeur dat het systeem verder is voorzien van een tweede bypass-verbinding voor het bij opstarten overbruggen van de tweede ingang en de tweede uitgang van de brandstofcel.

Volgens een zeer geschikte toepassing van het systeem volgens de uitvinding geldt dat het systeem verder is voorzien van een CV-circuit alsmede een derde warmte-wisselaar voor het uitwisselen van warmte tussen het eerste

verwarmingscircuit en het CV-circuit. Hierbij kan het CV-circuit zijn voorzien van een warmtewisselaar die stroomafwaarts van de eerste warmtewisselaar in het verbrandingstraject is opgenomen en die in combinatie met de naverbrander als boilersysteem kan functioneren. In het bijzonder geldt hierbij dat het eerste verwarmingscircuit is uitgevoerd als een reversibel-verwarmingscircuit waarin een warmtetransportmedium selectief in twee richtingen kan worden rondgepompt. Het eerste verwarmingscircuit heeft een dubbelfunctie. Bij opstart stroomt het fluïdum in het verwarmingscircuit van de eerste warmtewisselaar naar de brandstofcel, van de brandstofcel naar de derde warmtewisselaar en van de derde warmtewisselaar naar de eerste warmtewisselaar. De brander kan hierbij in bedrijf zijn en brandt op afgas van de afgasbrander en lucht via de tweede bypass van de brandstofcel. Hierbij verwarmen de verbrandingsgassen de brandstofcel.

Tijdens stationair bedrijf is de brander in principe buiten werking. Het fluïdum in het eerste verbrandingscircuit stroomt in een richting tegengesteld aan de richting bij opstarten. Dit brengt met zich dat de warmte van de brandstofcel wordt afgevoerd naar de derde warmtewisselaar die deel uitmaakt van de centrale verwarming. Indien de restwarmte naar deze warmtewisselaar in het fluïdum te groot is om de brandstofcel voldoende te koelen, kan de warmte uit het eerste verwarmingscircuit worden verwijderd met behulp van een in dit verwarmingscircuit opgenomen warmtevernietiger zoals een koelribbe. Als echter de brandstofcel geen voldoende warmte voor het CV-systeem genereert, kan de brander als boilerbrander worden ingezet. Hiertoe is de brander voorzien van een additionele aansluiting waaraan bijvoorbeeld aardgas kan worden toegevoerd. Verbrandingswarmte wordt dan via het eerste verwarmingscircuit en via de rookgassen van de brander naar het CV-circuit geleid.

In principe geldt voor het systeem dat de elektriciteitsvraag leidend is. De restenergievraag wordt gedekt door het inschakelen van de brander als boilerbrander.

De uitvinding zal thans nader worden toegelicht aan de hand van de tekening. Hierin toont:

Fig. 1 een principeschema van een mogelijke uitvoeringsvorm van het systeem volgens de uitvinding.

In fig. 1 is met verwijzingscijfer 1 een systeem volgens de uitvinding aangeduid. Het systeem is voorzien van een brandstofprocessor 2, voor het genereren van waterstof uit een koolwaterstofverbinding of een mengsel van koolwaterstofverbindingen. De brandstofprocessor is hiertoe voorzien van een eerste inlaat 4 voor het toevoeren van lucht en een tweede inlaat 6 voor het toevoeren van de gasvormige koolwaterstofverbinding of het mengsel van koolwaterstofverbindingen, in dit voorbeeld aardgas. Het systeem is verder voorzien van een verbrandingstraject waarlangs de door de brandstofprocessor 2 gegenereerde waterstof wordt geleid voor verbranding. Dit verbrandingstraject is in de figuur met de stippellijn 8 aangeduid.

In het verbrandingstraject 8 is een brandstofcel 10 van een op zich bekend type opgenomen voor het tenminste opwekken van elektrische energie E en eventueel warmte Q door verbranding van de door de brandstofprocessor 2 gegenereerde waterstof. De brandstofcel is in dit voorbeeld voorzien van een eerste ingang 12 die met een uitgang van de brandstofprocessor 2 is verbonden voor het toevoeren van waterstof aan de brandstofcel. Voorts is de brandstofcel voorzien van een tweede ingang 14 voor het toevoeren van lucht aan de brandstofcel. De brandstofcel is verder voorzien van een eerste uitgang 16 voor het afvoeren van afgas van een anode 18 van de brandstofcel en een tweede uitgang 20 voor het afvoeren van afgaslucht van een kathode 22 van de brandstofcel.

Het systeem is verder voorzien van een eerste warmtewisselaar 24 en een tweede warmtewisselaar 26 die enerzijds stroomafwaarts van de brandstofcel 10 in serie in het verbrandingstraject 8 zijn opgenomen. Het systeem omvat voorts een eerste verwarmingscircuit 28 waarin de brandstofcel is opgenomen en een tweede verwarmingscircuit 30 waarin de brandstofprocessor is opgenomen. Hierbij is de eerste warmtewisselaar anderzijds in het eerste verwarmingscircuit 28 opgenomen voor het uitwisselen van warmte tussen het verbrandingstraject 8 en het eerste verwarmingscircuit. De tweede warmtewisselaar 26 is anderzijds in het tweede verwarmingscircuit 30 opgenomen voor het uitwisselen van warmte tussen het verbrandingstraject 8 en het tweede verwarmingscircuit 30.

Het systeem is verder voorzien van een tussen de brandstofcel 10 en de tweede warmtewisselaar 26 in het verbrandingstraject opgenomen, op zich bekende, katalytische afgasbrander 32. Tussen de eerste warmtewisselaar 24 en de tweede warmtewisselaar 26 is in verbrandingstraject 8 een brander 34 opgenomen die de functie kan hebben van naverbrander of boilerbrander. Een en ander brengt met zich dat de brandstofcel 10, de afgasbrander 32, de tweede warmtewisselaar 26, de brander 34, en de eerste warmtewisselaar 24 respectievelijk in serie in het verbrandingstraject 8 zijn opgenomen. De brander 34 is verder voorzien van een separate ingang 36 voor het toevoeren van een gas zoals aardgas. De afgasbrander 32 is verder voorzien van tenminste een eerste ingang 38 die in het verbrandingstraject 8 is opgenomen en een tweede ingang 40 voor het toevoeren van lucht. In dit voorbeeld is de tweede uitgang 20 van de brandstofcel 10 met de tweede ingang 40 van de afgasbrander verbonden. Het is echter eveneens mogelijk dat de afgasbrander is voorzien van een separate ingang 40' voor de toevoer van lucht aan de afgasbrander. Het systeem is derhalve dusdanig ingericht dat afgaslucht afkomstig van de brandstofcel of lucht van elders aan de afgasbrander kan

worden toegevoerd via respectievelijk de ingang 40 dan wel 40'.

De eerste uitgang 16 van de brandstofcel 10 is met de in het verbrandingstraject 8 opgenomen eerste ingang 38 van de afgasbrander 32 verbonden. De tweede uitgang 20 van de brandstofcel is verbonden met de brander 34 voor het toevoeren van afgaslucht van de brandstofcel 10 aan de brander 34. In dit voorbeeld geldt dat de tweede uitgang 20 van de brandstofcel via een regelklep 42 tevens met de tweede ingang 40 van de afgasbrander is verbonden voor het toevoeren van afgaslucht of lucht aan de afgasbrander 32.

Het systeem is verder voorzien van een regelbare eerste bypass-verbinding 44 voor het bij opstarten van het systeem overbruggen van de eerste ingang 12 en de eerste uitgang 16 van de brandstofcel 10. Tevens is het systeem voorzien van een tweede bypass-verbinding 46 voor het bij opstarten overbruggen van de tweede ingang 14 en de tweede uitgang 20 van de brandstofcel 10. In dit voorbeeld omvat het systeem verder een CV-circuit 48 alsmede een derde warmtewisselaar 50 voor het uitwisselen van warmte tussen het eerste verwarmingscircuit 28 en het CV-circuit 48. Het CV-circuit 48 is voorzien van een warmtewisselaar 52 die stroomafwaarts van de eerste warmtewisselaar 24 in het verbrandingstraject 8 is opgenomen. Aldus wordt afgas dat de eerste warmtewisselaar heeft doorstroomd aan de warmtewisselaar 52 toegevoerd. Behalve de derde warmtewisselaar 50 en de warmtewisselaar 52 is tevens een CV 54 in het CV-circuit 48 opgenomen.

Het eerste verwarmingscircuit is in dit voorbeeld uitgevoerd als een reversible circuit waarin een warmtetransportmedium selectief in twee richtingen kan worden rondgepompt. Het systeem is verder nog voorzien van een warmtevernietiger 56 in de vorm van bijvoorbeeld een koelribbe die in het eerste verwarmingscircuit 28 tussen de brandstofcel 10 en de derde warmtewisselaar 50 is opgenomen

voor het afvoeren van een instelbare hoeveelheid warmte uit het eerste verwarmingscircuit 28.

In dit voorbeeld is de brandstofprocessor 2 voorzien van bevochtigingsmiddelen 58 voor het bevochtigen van een mengsel van aardgas en lucht, welk aardgas en lucht via de eerste inlaat 4 en de tweede inlaat 6 aan de brandstofprocessor wordt toegevoerd. De bevochtingsmiddelen 58 zijn hiertoe in dit voorbeeld voorzien van een reservoir met water dat in het tweede verwarmingscircuit 30 is opgenomen voor het verwarmen van het water en voor het aldus toevoegen van waterdamp aan het genoemde mengsel. De inrichting is verder nog voorzien van regelkleppen 60, 62 voor het instelbaar verdelen van de door de brandstofprocessor 2 gegenereerde waterstof naar de eerste ingang 12 van de brandstofcel 10 en de bypass 44. Voorts is de inrichting voorzien van kleppen 64, 66 voor het instelbaar verdelen van met behulp van een ventilator 68 aangezogen lucht over de tweede ingang 14 van de brandstofcel 10 en de tweede bypass 48. Met behulp van kleppen 70, 72 kan het medium dat het verwarmingscircuit 28 doorstroomt naar keuze geheel of gedeeltelijk door de warmtevernietiger 56 worden geleid.

Het systeem zoals hiervoor omschreven werkt als volgt.

Bij het opstarten is de brandstofprocessor nog niet opgewarmd en zal derhalve nog geen waterstofrijk gas kunnen genereren. In een eerste stap wordt aardgas naar de brandstofprocessor gevoerd, gemengd met een ondermaat verbrandingslucht. In de processor wordt dit mengsel verbrand, waarbij CO en H_2 ontstaat. De verbranding kan thermisch of katalytisch plaatsvinden, met behulp van respectievelijk een elektrische ontsteking of een elektrische verwarming voor het opstarten van de katalysator. Bij het opstarten zijn de kleppen 60, 62 dusdanig ingesteld dat het mengsel van CO, H_2 en onverbrand aardgas dat de brandstofprocessor 2 verlaat via de bypass

44 aan de ingang 38 van de afgasbrander 32 wordt toegevoerd. Tevens zijn de kleppen 64, 66 dusdanig geschakeld dat met behulp van de ventilator 68 aangezogen lucht via bypass 46 en de regelklep 42 aan de brander 34 wordt toegevoerd. Tevens kan via de regelklep 42 bovendien een gedeelte van de genoemde lucht aan de ingang 40 van de afgasbrander 32 worden toegevoerd. De afgasbrander 32 wordt bij het opstarten met behulp van een verwarmingseenheid 74 van de afgasbrander verwarmd. De verwarmingseenheid 74 kan bijvoorbeeld zijn uitgevoerd als een elektrische verwarming. Het gevolg is dat het gasmengsel uit de brandstofprocessor 2 met de lucht in de afgasbrander 32 zal verbranden. Hierdoor zal de temperatuur van de afgasbrander verder gaan stijgen. Het aldus ontstane afgas van de afgasbrander 32 wordt via de tweede warmtewisselaar 26 aan de brander 34 toegevoerd. Zoals besproken wordt aan de brander 34 tevens lucht toegevoerd. Onverbrande componenten die nog in het afgas aanwezig zijn worden in brander 34 verbrand, waarna het aldus gegenereerde afgas aan de eerste warmtewisselaar 24 wordt toegevoerd.

Bij het opstarten wordt met behulp van een pomp 76 een warmtetransportmedium van het tweede verwarmingscircuit 30 dusdanig rondgepompt dat dit medium van de tweede warmtewisselaar 26 naar de bevochtigingsmiddelen 58 van de brandstofprocessor stroomt. Het gevolg is dat waterdamp wordt toegevoegd aan het mengsel van lucht en aardgas dat via de eerste inlaat 4 en de tweede inlaat 6 aan de brandstofprocessor wordt toegevoerd. Hierdoor zal de brandstofprocessor beginnen met het genereren van waterstofrijk gas. Het volledig op gang komen van deze H_2 productie kan tot enkele uren in beslag nemen. Tijdens deze periode wordt met behulp van een pomp 78 die in het verwarmingscircuit is opgenomen een warmtetransportmedium dusdanig rondgepompt dat dit warmtetransportmedium stroomt van de eerste warmtewisselaar 24 naar de brandstofcel 10, van de brandstofcel 10 naar de derde warmtewisselaar 50 en

van de derde warmtewisselaar 50 terug naar de eerste warmtewisselaar 24. Het gevolg is dat de brandstofcel 10 eveneens wordt opgewarmd.

Wanneer de brandstofcel 10 is opgewarmd, terwijl bovendien de brandstofprocessor waterstofrijk gas genereert, worden de kleppen 60 en 62 dusdanig geschakeld dat de waterstof die door de brandstofprocessor 2 wordt gegenereerd aan de eerste ingang 12 van brandstofcel wordt toegevoerd. De eerste bypass 44 wordt buiten werking gesteld. Tevens wordt de met behulp van de ventilator 68 aangezogen lucht aan de tweede ingang 14 van de brandstofcel toegevoerd. Dit betekent dat de tweede bypass 46 eveneens buiten werking wordt gesteld. Bovendien treedt de brander 34 buiten werking. Daarnaast wordt de pomp 78 dusdanig aangestuurd dat deze het warmtetransportmedium in een tegengestelde richting gaat rondpompen, d.w.z. van de brandstofcel 10 naar de eerste warmtewisselaar 24, van de eerste warmtewisselaar 24 naar de derde warmtewisselaar 50 en van de derde warmtewisselaar 50 terug naar de brandstofcel 10.

In deze situatie zal het waterstofgas dat aan brandstofcel 10 wordt toegevoerd, althans gedeeltelijk, verbranden. Hierdoor zal de brandstofcel 10 elektrisch vermogen E genereren dat wordt aangeboden voor bijvoorbeeld het gebruik van elektriciteit in een woning. Het afgas wordt via de uitgang 16 van de anode 18 aan de ingang 38 van de afgasbrander toegevoerd. Tegelijkertijd wordt een deel van de afgaslucht van de uitgang 20 van de kathode via de regelklep 42 aan de ingang 40 van de afgasbrander toegevoerd. De regelklep is zodanig ingesteld dat het resterende deel van de afgaslucht van de uitgang 20 van de kathode de brander 34 blijft doorstromen, ook nadat deze is gedoofd. In de afgasbrander wordt het afgas afkomstig van de brandstofcel 10 voorzover de waterstof hierin nog niet volledig was verbrand verder verbrand. Het afgas dat hierbij in de afgasbrander 32 wordt geproduceerd,

doorstroomt vervolgens de tweede warmtewisselaar 26, de brander 34 die is gedoofd en de eerste warmtewisselaar 24. De tweede warmtewisselaar 26 zorgt ervoor dat continu warmte aan de bevochtigingsmiddelen 58 wordt toegevoerd. De eerste warmtewisselaar 24 heeft thans als functie ervoor te zorgen dat de brandstofcel 10 wordt gekoeld. Warmte wordt via de tweede warmtewisselaar 24 aan de derde warmtewisselaar 50 toegevoerd. De tweede warmtewisselaar 50 geeft hierbij warmte af aan het CV-circuit 48. Voorts wordt het afgas dat de eerste warmtewisselaar 24 heeft doorstroomd aan de warmtewisselaar 52 toegevoerd. Het medium dat het CV-circuit 48 doorstroomt geeft zijn warmte vervolgens af aan de centrale verwarming 54 die in een woning op zich bekende radiatoren kan omvatten. De warmtewisselaar 52 is in dit voorbeeld voorzien van een temperatuursensor 80 voor het meten van de temperatuur van het medium dat door het CV-circuit 48 stroomt. Wanneer blijkt dat de temperatuur niet voldoende hoog is om te kunnen voldoen aan de door de centrale verwarming 54 gevraagde hoeveelheid warmte, kan de brander 34 worden geactiveerd zodat deze gaat fungeren als boilerbrander. Een klep 79 wordt hiertoe geopend. Hiertoe wordt dan via de ingang 36 aardgas aan de brander 34 toegevoerd. Dit heeft weer tot gevolg dat het afgas van de afgasbrander 32 dat de brander 34 doorstroomt verder zal worden verwarmd. Dit verwarmde afgas, gemengd met rookgas van brander 34, doorstroomt de eerste warmtewisselaar en kan aldus een deel van de warmte-inhoud afgeven aan het verwarmingscircuit 28 die vervolgens op zijn beurt via de derde warmtewisselaar 50 warmte afgeeft aan het CV-circuit. Het mengsel van rookgas en afgas stroomt na de eerste warmtewisselaar 24 via verbrandingstraject 8 naar de warmtewisselaar 52, waar het gas een volgend deel van de warmte-inhoud afstaat aan het CV-circuit. De brander 34 en warmtewisselaar 52 gaan zo fungeren als boiler.

Het toepassen van een katalytische afgasbrander heeft verder als voordeel dat piekbelastingen goed kunnen worden opgevangen.

Wanneer bijvoorbeeld de elektriciteitsvraag laag is en uit de brandstofcel slechts een geringe hoeveelheid restwaterstof via de uitgang 16 naar de ingang 38 van de afgasbranders stroomt, is de afgasbrander toch in staat dit goed te verbranden. Wanneer echter de elektriciteitsvraag hoog is en relatief veel restwaterstof wordt afgegeven door de brandstofcel, kan de afgasbrander eveneens goed functioneren. Wanneer de samenstelling van het afgas, dat via bypass 44 uit de brandstofprocessor 2 wordt toegevoerd aan de ingang 38 van de afgasbrander, tijdens de opstart sterk varieert, door de overgang van afgas met relatief veel onverbrand aardgas naar een waterstofrijk mengsel, is de afgasbrander toch in staat dit variërende mengsel goed te verbranden.

Het is eveneens mogelijk dat de afgasbrander via een separate ingang 40' wordt voorzien van lucht. In dat geval kan de regelklep 42 worden weggelaten. De tweede uitgang 20 is dan uitsluitend verbonden met de naverbrander 34.

Het systeem is verder voorzien van een besturingsinrichting 82 voor het besturen van de kleppen 42, 60, 62, 64, 66, 70 en 72, zoals hiervoor besproken. Tevens bestuurt de controle-inrichting 82 de ventilator 68 en 84, de pomp 76, de pomp 78, de boiler 52 en de centrale verwarming 54 zoals hiervoor besproken. De controle-eenheid 82 is tevens verbonden met de temperatuurmeetsensor 80 voor het bepalen of het noodzakelijk is de brander 34 in te schakelen als boilerbrander zoals hiervoor besproken. De controle-eenheid 82 bestuurt dienovereenkomstig de brander 34 alsmede de klep 79 voor de toevoer van aardgas aan de ingang 36 van de brander zoals hiervoor besproken.

De uitvinding is geenszins beperkt tot de hiervoor geschetste uitvoeringsvormen. Zo is het mogelijk dat de brander 34 wordt voorzien van een separate ingang voor de

toevoer van lucht. Het is derhalve niet noodzakelijk dat de brander wordt voorzien van lucht die afkomstig is van de ventilator 68 en die al dan niet via de brandstofcel 10 en/of de bypass 56 aan de brander wordt toegevoerd. In dat geval kan de bypass 56 achterwege blijven. Dergelijke varianten worden elk geacht binnen het kader van de uitvinding te vallen.

CONCLUSIES

1. Systeem voorzien van een brandstofprocessor voor het genereren van waterstof uit een koolwaterstof-verbinding en een verbrandingstraject waarlangs de gegenereerde waterstof wordt geleid voor verbranding, waarbij in het verbrandingstraject tenminste een brandstofcel is opgenomen voor het tenminste opwekken van elektrische energie en eventueel warmte door verbranding van de door de brandstofprocessor gegenereerde waterstof, met het kenmerk, dat het systeem verder is voorzien van een eerste warmtewisselaar en een tweede warmtewisselaar die enerzijds stroomafwaarts van de brandstofcel in serie in het verbrandingstraject zijn opgenomen, een eerste verwarmingscircuit waarin de brandstofcel is opgenomen en een tweede verwarmingscircuit waarin de brandstofprocessor is opgenomen waarbij de eerste warmtewisselaar anderzijds in het eerste verwarmingscircuit is opgenomen voor het uitwisselen van warmte tussen het verbrandingstraject en het eerste verwarmingscircuit en de tweede warmtewisselaar anderzijds in het tweede verwarmingscircuit is opgenomen voor het uitwisselen van warmte tussen het verbrandingstraject en het tweede verwarmingscircuit.

2. Systeem volgens conclusie 1, met het kenmerk, dat het systeem verder is voorzien van een tussen de brandstofcel en de tweede warmtewisselaar in het verbrandingstraject opgenomen afgasbrander.

3. Systeem volgens conclusie 1 of 2, met het kenmerk, dat het systeem verder is voorzien van een tussen de eerste en tweede warmtewisselaar in het verbrandingstraject opgenomen naverbrander of boilerbrander.

4. Systeem volgens conclusie 2 en 3, met het kenmerk, dat de brandstofcel, afgasbrander, tweede warmtewisselaar, naverbrander en eerste warmtewisselaar respectievelijk in serie zijn geschakeld.

5. Systeem volgens conclusie 3 of 4, met het kenmerk, dat de naverbrander verder is voorzien van een separate ingang voor het toevoeren van een gas zoals aardgas.

6. Systeem volgens een der conclusies 2, 4 of 5, met het kenmerk, dat de afgasbrander verder is voorzien van tenminste een eerste ingang die in het verbrandingstraject is opgenomen en een tweede ingang voor het toevoeren van lucht.

7. Systeem volgens conclusie 6, met het kenmerk, dat het systeem dusdanig is ingericht dat afgaslucht afkomstig van de brandstofcel of lucht van elders aan de afgasbrander kan worden toegevoerd.

8. Systeem volgens een der voorgaande conclusies, met het kenmerk, dat de brandstofcel is voorzien van een eerste ingang die met de brandstofprocessor is verbonden voor het toevoeren van de waterstof aan de brandstofcel, een tweede ingang voor het toevoeren van lucht aan de brandstofcel, een eerste uitgang voor het afvoeren van afgas van een anode van de brandstofcel en een tweede uitgang voor het afvoeren van afgaslucht van een kathode van de brandstofcel.

9. Systeem volgens conclusie 7 en 8, met het kenmerk, dat de eerste uitgang van de brandstofcel met de in het verbrandingstraject opgenomen eerste ingang van de afgasbrander is verbonden.

10. Systeem volgens conclusie 9, met het kenmerk, dat de tweede uitgang van de brandstofcel met de naverbrander is verbonden voor het toevoeren van afgaslucht van de brandstofcel aan de naverbrander.

11. Systeem volgens conclusie 10, met het kenmerk, dat de tweede uitgang via een regelklep tevens met de tweede ingang van de afgasbrander is verbonden voor het toevoeren van afgaslucht aan de afgasbrander.

12. Systeem volgens een der conclusies 8-11, met het kenmerk, dat het systeem verder is voorzien van een regelbare eerste bypass-verbinding voor het bij opstarten

van het systeem overbruggen van de eerste ingang en de eerste uitgang van de brandstofcel.

13. Systeem volgens conclusie 12, met het kenmerk, dat het systeem verder is voorzien van eën tweede bypass-verbinding voor het bij opstarten van het systeem overbruggen van de tweede ingang en de tweede uitgang van de brandstofcel.

14. Systeem volgens een der voorgaande conclusies, met het kenmerk, dat het systeem verder is voorzien van een CV-circuit alsmede een derde warmtewisselaar voor het uitwisselen van warmte tussen het eerste verwarmingscircuit en het CV-circuit.

15. Systeem volgens conclusie 14, met het kenmerk, dat het CV-circuit is voorzien van een warmtewisselaar die stroomafwaarts van de eerste warmtewiselaar in het verbrandingstraject is opgenomen

16. Systeem volgens conclusie 14 of 15, met het kenmerk, dat het eerste verwarmingscircuit is uitgevoerd als een reversibel-verwarmingscircuit waarin een warmtetransport-medium selectief in twee richtingen kan worden rondgepompt.

17. Systeem volgens conclusie 14, 15 of 16, met het kenmerk, dat het systeem verder is voorzien van een warmtevernietiger in de vorm van bijvoorbeeld een koelribbe die in het eerste verwarmingscircuit tussen de brandstofcel en de derde warmtewisselaar is opgenomen voor het instelbaar afvoeren van warmte uit het eerste verwarmings-circuit wanneer de brandstofcel, in gebruik, na het opstarten niet voldoende kan worden gekoeld.

18. Systeem volgens een der voorgaande conclusies, met het kenmerk, dat de brandstofprocessor is voorzien van bevochtigingsmiddelen voor het bevochtigen van de aan de brandstofprocessor toegevoerde koolwaterstoffen waarbij de bevochtigingsinrichting in het tweede verwarmingscircuit is opgenomen voor het toevoeren van warmte aan de bevochti-gingsmiddelen.

UITTREKSEL

Het systeem is voorzien van een brandstofprocessor voor het genereren van waterstof uit een koolwaterstof-verbinding of uit mengsels van koolwaterstofverbindingen en een verbrandingstraject waarlangs de gegenereerde waterstof wordt geleid voor verbranding. In het verbrandingstraject tenminste een brandstofcel is opgenomen voor het opwekken van elektrische energie. Het systeem verder is voorzien van een eerste warmtewisselaar en een tweede warmtewisselaar die enerzijds stroomafwaarts van de brandstofcel in serie in het verbrandingstraject zijn opgenomen, een eerste verwarmingscircuit waarin de brandstofcel is opgenomen en een tweede verwarmingscircuit waarin de brandstofprocessor is opgenomen. De eerste warmtewisselaar is anderzijds in het eerste verwarmingscircuit opgenomen. De tweede warmte-wisselaar is anderzijds in het tweede verwarmingscircuit is opgenomen.